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A MONOGRAPH

OF THE

BRITISH FOSSIL CRUSTACEA,

BELONGING TO THE

ORDER MEROSTOMATA.

BY

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RADCLIFFE

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PREFACE.

SINCE, of late years, the conclusion has become very generally accepted among Naturalists that the development of the embryo of any animal is but a recapitulation of the ancestral history of the species to which it belongs, a new impulse has been imparted alike both to embryological and palæontological research, for each furnishes most valuable and independent evidence by which to demonstrate the correctness or fallibility of the doctrine of Evolution.

But whilst, on the one hand, the reconstruction of the pedigree of a group from the developmental history of its existing members is admittedly fraught with difficulties—for the series of developmental stages of the individual organism probably never presents more than an abbreviated and condensed summary of ancestral conditions, whilst the summary itself is oftentimes strangely modified—on the other hand, the palæontologist is only too well aware that the materials at his command merely enable him to furnish an outline of the ancestry of many of the groups most largely represented at the present day.

There is, perhaps, no group among the fossil Crustacea which affords such ample materials for comparison with recent forms as the order MEROSTOMATA.

Extending back in time to the Lower Silurian Rocks, these ancient forms not only portray the larval stages of the highest forms of living Crustacea, but they also foreshadow the incoming of the air-breathing ARACHNIDA, whose ancestors they probably were.

Another interesting feature of the order is its bipartite division into brachyuran and macrouran forms which exemplify the crawling and swimming types, by the soldering together of the body-segments in the one (*Limulus*), and the retention of free movement in the somites of the other (*Pterygotus*).

Numerous species of the ancient extinct long-bodied EURYPTERIDA have been met with and described by Prof. James Hall in America, by Fischer and Nieszkowski in Russia and Sweden, and by Huxley and Salter and by myself in Britain.

The most perfect specimens of the genera *Slimonia*, *Pterygotus*, and *Eurypterus*, have been obtained by Dr. J. Slimon, of Lesmahagow, Lanark. The largest known remains, representing specimens from five to six feet in length, are from the Old Red Sandstone of Forfarshire, belonging to the great *Pterygotus anglicus* and *Stylonurus scoticus*, obtained by James Powrie, Esq., F.G.S., of Reswallie, Forfar.

In the Upper Silurian we have one English genus, *Hemiaspis*, and three Russian forms, *Exapinurus*, *Pseudoniscus*, and *Bunodes*, which, like the Decapoda-Anomoura, serve partially to bridge over the interval between the brachyuran *Limuli* and the macrouran *Pterygoti*, the segments of the hind-body being partially developed.

The EURYPTERIDA are eminently larval in their characteristics, and recall to mind the earliest stages in the development of the living Brachyuran Decapod (e. g. *Carcinus mœnas*), in which the principal locomotory organs are the maxillipeds, the branchiæ (if developed) being external and thoracic, the abdominal somites in both being destitute of appendages. Like the larva of these higher forms, too, they have doubtless undergone further modification, and so in the course of ages this primitive type has disappeared. The latest representative of this extinct order has been found in the Lower Carboniferous series of West Lothian, the *Eurypterus Scouleri*, which, however, differs greatly from all the other earlier forms.

The brachyuran type, or XIPHOSURA, are represented by a very minute form with free thoracico-abdominal somites in the Upper Silurian of Lesmahagow, Lanarkshire, the *Neolimulus falcatus*, and by numerous species in the Coal-measures of Great Britain and Ireland, the United States, Germany, and Bohemia. Some of these forms belonging to the genus *Bellinurus* had free thoracic somites, and others, like *Prestwichia rotundata*, forcibly remind one of the free-swimming larvæ of the modern King-Crab. In the Oolitic period the *Limuli* seem to have already attained to the greatest development of which they were capable, and to be as highly differentiated as their modern representatives, *Limulus polyphemus* and *L. moluccanus*.

The OSTRACODA, PHYLLOPODA, and XIPHOSURA are good examples of persistent types of Crustacea. They are orders the members of which have branched out long since into bye-ways of their own, where, being checked from further progress, they have by their great tenacity of life and large powers of reproduction held their ground through the long lapse of ages from Cambro-Silurian times to the present day, whilst higher orders have been modified or swept away.

H. W.

117, BEAUFORT STREET, CHELSEA,
LONDON, S.W.;
21st February, 1878.

A MONOGRAPH
OF THE
BRITISH FOSSIL CRUSTACEA
OF THE
ORDER MEROSTOMATA.

PART I.

INTRODUCTION.

THE history of the Fossil CRUSTACEA of the British Islands cannot any longer be spoken of as a neglected subject.

Apart from the numerous papers thereon which have appeared in the various publications of the day, no fewer than ten Monographs of this class have been issued by the Palæontographical Society alone,[1] and one by the Geological Survey of Great Britain;[1] to this latter work especial reference will frequently be made hereafter.

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[1] 'On the Cretaceous Entomostraca,' by Prof. T. Rupert Jones, F.G.S., &c., 1849.
'On the Tertiary Entomostraca,' by the same Author, 1856.
'On the Fossil Estheriæ,' by the same Author, 1862.
'On the Fossil Lepadidæ,' by Charles Darwin, F.R.S., F.G.S., 1851.
'On the Fossil Balanidæ and Verrucidæ,' by the same Author, 1854.
'On the Crustacea of the London Clay,' by Prof. Bell, F.R.S., F.G.S., &c., 1858.
'On the Crustacea of the Gault and Greensand,' by the same Author, 1862.
'British Trilobites,' by J. W. Salter, A.L.S., F.G.S., 1864.
" Part ii, by the same Author, 1865.
" Part iii " 1866.

The *Crustacea* are included in the sub-kingdom ARTICULATA, and are characterised by a body divided into rings or segments, more or less distinct and moveable, and protected by a horny or calcareous exo-skeleton, provided with articulated limbs arranged in pairs, usually five[2] to seven[3] in number.

The class is essentially aquatic, breathing by branchiæ; and, although some members subsist on land, their organs of respiration are true branchiæ, and quite dissimilar from the tracheæ of insects.

Before attaining the adult condition the marine species pass through a series of embryonic changes, apparently more numerous in the higher forms.[4] Every part that is present in the larva, though not permanent in the individual, is to be found in a permanent condition in one or other form of adult *Crustacea* of a lower order than that to which it belongs.[5]

Even after arriving at the adult state the shelly envelope is not permanently retained, but is exuviated as often as the growth of the animal necessitates its enlargement. In the perfect Insect, on the contrary, the exo-skeleton is retained, and no increase of growth or reproduction of lost appendages takes place in the *imago*, as among mature *Crustacea*.

Previous to describing the order which forms the subject of this Monograph, it will be well to speak of the type on which the class is constructed. By the 'type,' we understand that example of any natural group which possesses all the leading characters of that group. For it must be borne in mind, that every division of animals, whether vertebrate or invertebrate, necessarily includes within its limits genera most dissimilar from the type-form upon which the class is constructed. No one, for example, would select the *Ornithorhynchus* as a typical mammal, or the *Apteryx* as a typical bird, the tunicated *Botryllus* as a type-mollusk, or the *Balanus* as a type-crustacean.

Indeed, the type of any class or order is not to be sought for at the extremity of the series, but near the centre.

Dr. Milne-Edwards[6] writes, "The normal number of segments is twenty-one." . . . "By general consent and usage three regions are recognised in the bodies of these animals—a *head*, a *thorax*, and an *abdomen;* and from this custom we shall not depart, although we must avow that these denominations are only derived from very clumsy views, and are calculated to convey false impressions in regard to the nature and composition of the parts so named, by leading the mind to liken them to the grand divisions entitled head, thorax, and abdomen, in the Vertebrata.

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[1] 'Memoirs of the Geol. Survey of the United Kingdom,' Monograph I, 1859. "On the Anatomy and Affinities of the Genus *Pterygotus*," by Prof. T. H. Huxley, F.R.S., &c., with "Descriptions of the Species," by J. W. Salter, F.G.S., A.L.S.

[2] In the *Decapoda*.

[3] In the *Isopoda*.

[4] The land and freshwater *Decapoda*, as well as the sessile-eyed forms, apparently undergo these embryonic changes in the ova, the young nearly resembling the parent when excluded from the egg. See also Prof. Bell's "Hist. Brit. Stalk-eyed Crustacea,' Introduction, pp. xliv—xlvi; and Prof. Owen's Lectures, 1855, pp. 334-342.

[5] Spence Bate, "On the Development of Decapod Crustacea," 'Phil. Trans.,' 1858, p. 602.

[6] See article *Crustacea*, by Dr. Milne-Edwards, in Todd's 'Cyclopædia of Anatomy,' vol. i, 1836, p. 754.

"Nevertheless, with the exception of the objectionable names, the division of the body into three regions is not less a fact as regards the organization of the *Crustacea;* and the one and twenty rings of which, as we have said, their body consists in the type to which every member of the class may be referred, are generally found divided into three equal series of seven, each of which may be held as corresponding with one of the three regions."

Dr. Dana, in his great work[1] on the *Crustacea,* distinguishes this class from the *Insecta* by its possessing a cephalothorax and an abdomen; the former having 14 segments, the latter 7.

The views of Mr. C. Spence Bate[2] and Mr. J. O. Westwood[3] differ but little from those of Dr. Milne-Edwards. Mr. Spence Bate[4] objects even more strongly to the use of the names 'thorax' and 'abdomen,' as applied to *Crustacea,* than Milne-Edwards, and recommends instead the terms 'pereion'[5] and 'pleon,'[6] as less calculated to mislead the student as to the homologies of the divisions of the body. But any names, however well devised, must fail to meet all the requirements of a class so diversified in its various orders as this. The frequent interblending of a part, or the whole, of the segments of the second division of the body with the head of the animal, necessitating a term like 'cephalothorax' to express it, has been the chief reason for their retention, and long usage must command a certain amount of respect even for a "clumsy" term.[7]

Prof. Huxley, in his lectures on the *Crustacea,*[8] divides the body into 6 cephalic, 8 thoracic, and 6 abdominal segments or somites. He considers the caudal segment, or telson, not to be a segment, properly so called, but a peculiar median appendage; thus reducing them to 20 in all.

We give these several views on the adjoining page, and shall discuss their applicability as we proceed.

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[1] 'United States Expl. Exped. 1852, Crustacea,' by J. D. Dana, vol. xiii, part i, p. 21.

[2] See 'Brit. Assoc. Report,' 1855, by Mr. C. Spence Bate, "On the British *Edriophthalma,*" p. 27.

[3] C. Spence Bate and J. O. Westwood, on 'British Sessile-eyed Crustacea,' part i, p. 3, 1861.

[4] C. Spence Bate, "On the Development of Decapod Crustacea,' 'Phil. Trans.,' 1858, p. 590.

[5] From *περαιόω, to walk about.*

[6] From *πλέω, to navigate.*

[7] The terms 'head,' 'thorax,' and 'abdomen' are still retained by Entomologists for the class *Insecta,* although some of the objections to their use in the *Crustacea* also hold good in that class.

[8] "Lectures on the Crustacea," by Prof. T. H. Huxley, F.R.S., 'Medical Times and Gazette,' 1857, p. 507.

ARRANGEMENT AND NOMENCLATURE OF THE SEGMENTS OR

(*According to the*

	I. Segments of the Head (*Edwards, Bell*, &c. &c.)		I. Segments of the Cephalothorax (*Dana*).[2]
I.	1. Bearing the Eyes.	I.	1. Ophthalmic Segment.
II.	2. „ „ Antennules, or Internal Antennæ.	II.	2. 1st Antennary „
III.	3. „ „ External Antennæ.	III.	3. 2nd „ „
IV.	4. „ „ Mandibles.	IV.	4. Mandibular „
V.	5. „ „ 1st Maxillæ.	V.	5. 5th to 14th Segments, Maxillary, and Podal, 10 pairs.
VI.	6. „ „ 2nd „	VI.	6.
VII.	7. „ „ Maxillipeds.	VII.	7.
	II. Segments of the Thorax.		
VIII.	1. Bearing the 2nd Maxillipeds.	VIII.	8.
IX.	2. „ „ 3rd „	IX.	9.
X.	3. Either furnished with organs of prehension or Ambulatory or Natatory appendages.	X.	10.
XI.	4.	XI.	11.
XII.	5.	XII.	12.
XIII.	6.	XIII.	13.
XIV.	7.	XIV.	14.
	III. Abdomen.		II. Abdomen.
XV.	1. Usually furnished with swimming feet, or false abdominal feet; rudimentary in the Brachyura; branchiferous in Squilla; ovigerous in the females of nearly all genera.	XV.	15. 15th to 19th Segment, bearing abdominal feet.
XVI.	2.	XVI.	16.
XVII.	3.	XVII.	17.
XVIII.	4.	XVIII.	18.
XIX.	5.	XIX.	19.
XX.	6.	XX.	20. Segment, bearing caudal abdominal appendages, 1 pair.
XXI.	7. Caudal segment destitute of appendages.[1]	XXI.	21st. Or caudal segment without appendages.

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[1] Prof. Bell considers the extremely minute and moveable points attached to the extremity of this segment in *Palæmon serratus* to be a pair of rudimentary appendages.—[See Introduction to 'Bell's Hist. British Stalk-eyed Crustacea,' p. xx, 1853.]

[2] "Crustacea have a cephalothorax, but not a head"—*Dana, on Homologies of Crustacea*.—'United States Explg. Expedition,' Crustacea, vol. xiii, p. 21, 1852.

BODY-RINGS OF THE CRUSTACEA, WITH THEIR APPENDAGES.

principal authorities.)

	I. Cephalon. (*C. Spence Bate*).[1]		I. Cephalic Somites (*Huxley*).
I.	1. Somite or Segment, bearing the Eyes.	I.	1. Somite, bearing the Eyes.
II.	2. Ditto, bearing the 1st Antennæ.	II.	2. „ „ „ Antennules.
III.	3. „ „ 2nd Antennæ.	III.	3. „ „ „ Antennæ.
IV.	4. „ „ Mandibles.	IV.	4. „ „ „ Mandibles.
V.	5. „ „ 1st Maxillæ, or 1st Siagonopoda.	V.	5. „ „ „ 1st Maxillæ.
VI.	6. „ „ 2nd Maxillæ, or 2nd Siagonopoda.	VI.	6. „ „ „ 2nd „
			II. Thoracic Somites.
VII.	7. „ „ Maxillipeds, or 3rd Siagonopoda.	VII.	1. Somite, bearing 1st Maxillipeds.
	II. Pereion.		
VIII.	1. Bearing the 1st pair of appendages or Gnathopoda, or 4th Siagonopoda.	VIII.	2. „ „ 2nd
IX.	2. The 2nd pair of appendages or Gnathopoda, or 5th Siagonopoda.	IX.	3. „ „ 3rd „
X.	3. The 3rd pair of legs, or 1st Pereiopoda.	X.	4. } 4th to 8th Somites, bearing Ambulatory legs.
XI.	4. „ 4th „ 2nd „	XI.	5.
XII.	5. „ 5th „ 3rd „	XII.	6.
XIII.	6. „ 6th „ 4th „	XIII.	7.
XIV.	7. „ 7th „ 5th „	XIV.	8.
	III. Pleon.		III. Abdomen.
XV.	1. 1st Natatory legs or 1st Pleopoda.	XV.	1. } Each Somite furnished with a pair of appendages.
XVI.	2. 2nd „ 2nd „	XVI.	2.
XVII.	3. 3rd „ 3rd „	XVII.	3.
XVIII.	4. 1st Caudal appendages, 4th „ or 1st Uropoda.	XVIII.	4.
XIX.	5. 2nd „ 5th Pleopoda, or 2nd Uropoda.	XIX.	5.
XX.	6. 3rd „ 6th Pleopoda, or 3rd Uropoda.	XX.	6.
XXI.	7. Telson, Terminal joint, or middle tail-piece.	(21.[2])	"Telson," or median appendage, not furnished with any articulate limbs.[2]

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[1] See Report on the "British Edriophthalma" ('British Assoc. Report' for 1855, by C. Spence Bate, when these terms were first introduced. See also 'History of British Sessile-eyed Crustacea,' by C. Spence Bate, F.L.S., and J. O. Westwood, M.A., F.L.S., Part i, p. 3. October, 1861. London: Van Voorst.

[2] "The last segment never bears true appendages, and is developed subsequently to the others from the dorsal surface of the body. Hence we are justified in regarding it, not as a somite, but as a peculiar median appendix to which the special name 'telson' [C. Spence Bate] may be applied."—See Prof. Huxley's Lectures, 'Medical Times and Gazette,' 1857.

We have seen that the generally accepted type-number of body-rings, or somites, is twenty-one; but in the fossil *Trilobita*,[1] and the recent *Phyllopoda* and *Branchiopoda*, we have instances in which a larger number of segments occur. On the other hand, we occasionally meet with forms, both recent and fossil, in which one or more segments are never developed; but in general their apparent absence is due to their coalescence, and we shall frequently find indications of this if we bear in mind the theory of Oken, that each pair of appendages indicate a separate segment.

In the illustrations of recent Crustacea which we have given on Plate IX we have numbered the somites of figs. 1, 2, 3, 4, and 5, so as to show at a glance how many segments are united to form the head in each, as indicated by the figure placed upon it.

The restored figures of *Pterygotus anglicus*, Ag., Plate VIII, are also similarly numbered.

"In the embryo these segments are formed in succession from before backwards, so that, when their evolution is checked, the later, rather than the earlier rings, are those that are wanting; and, in fact, it is generally easy to see in those specimens of full-grown crustaceous animals whose bodies present fewer than twenty-one segments that the anomaly depends on the absence of a certain number of the most posterior rings of the body."[2]

Just as we find a typical number of twenty-one body-segments to prevail among the Crustacea, so also in the appendages, the type number of joints is seven, any departure from which is disguised by fusion of one or more joints together, the obsolete condition of others, or the depauperization of the limb into numerous *articuli*. (C. Spence Bate.)

The walking leg of a Decapod Crustacean (see woodcut, fig. 1), or the maxillipede[3] of *Pterygotus anglicus* (see woodcut, fig. 2), will serve as illustrations of limbs having the type-number of joints, which we will designate as follows:

Coxa . . .	1
Basos . . .	2
Ischium . . .	3
Meros . . .	4
Carpus . . .	5
Propodos . . .	6
Dactylus . . .	7

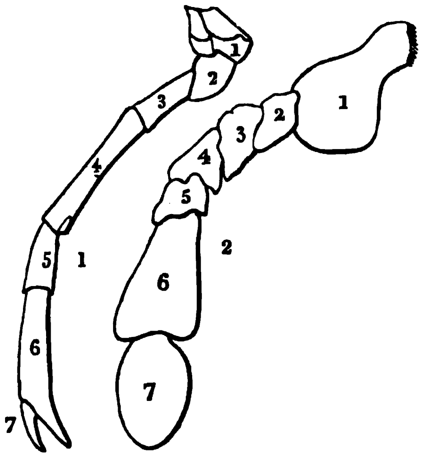

FIG. 1. Walking leg of Decapod.

FIG. 2. Jaw-foot of *Pterygotus*.[3]

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[1] See Mr. Salter's Monographs on the *Trilobita*, Pal. Soc., 1864-6.

[2] Milne-Edwards, 'Todd's Cycl. Anat.,' Article *Crustacea*, p. 753.

[3] 'Ectognath' of Prof. Huxley, 'Geol. Surv.,' Mon. I, 1859, p. 19.

These terms, used by Mr. C. Spence Bate[1] for the several joints of the limbs of Crustacea, are merely abbreviations of Milne-Edwards's terms *coxopodite*, *basipodite*, &c., *coxognathite*, *basignathite*, &c. The appendage may be a *podoite*, or a *gnathite;* but it seems superfluous to repeat the term at every joint, especially in treating of the limbs of *Pterygotus*, which are gnathopodites, or jaw-feet.

The common Lobster and Prawn are very good typical forms; but it is impossible to offer in one view any general classification of the appendages of *Crustacea* which is suitable to the whole group; for the limbs, subservient to one purpose in the Decapod, fulfil a totally different function in the Stomapod or Branchiopod; or the segments themselves are so welded together in the one, and so separated in the other, as to require much careful examination in order to discover their homologies.

Indeed the only segment that may be said to be persistent, is that which supports the mandibles, for the eyes may be wanting, and the antennæ, though less liable to changes than the remaining appendages, are nevertheless subject to very extraordinary modifications, and have to perform functions equally various. Being essentially and typically organs of touch, hearing, and perhaps of smell, in the highest Decapods, they become converted into burrowing organs in the *Scyllaridæ*, organs of prehension in the *Merostomata*, swimming organs and claspers for the male in the *Cyclopoidea*, and organs of attachment in the *Cirripedia*.

Not to multiply instances, we have presented to us in the *Crustacea* probably the best zoological illustration of a class, constructed on a common type, retaining its general characteristics, but capable of endless modification of its parts so as to suit the extreme requirements of every separate species.

And it is doubtless in some degree due to this plasticity of structure, enabling the species to occupy such diverse positions, and to subsist upon such varied aliment, that the class owes its preservation through the lapse of ages represented by the long series of geological formations, from the very oldest Silurian strata to the present day.

It is interesting to review the long and laborious methods by which the fragmentary fossil remains of the ancient order of the *Eurypterida* have, by the labours of Agassiz, M'Coy, Hall, Huxley, Salter, and others, been made, after frequent readjustment, not only to fit together correctly, so as to furnish us with a notion of their living forms, but also to take their appropriate places in the class and order to which they belong.[2]

As I shall have frequent occasion to refer to the published labours of these gentlemen in the course of this Monograph, I will not further allude to them here.

The additional materials which have accumulated during the past eight years sufficiently explain the necessity for the commencement of a fresh Monograph, and I am happy to state, that, in undertaking it I have received the approval and kind assistance of my scientific colleagues, both in the British Museum and in the Museum of Practical Geology; and those gentlemen whose collections can best illustrate the work in hand have obligingly opened their museums for my use and reference. My warmest thanks are due to Prof. John Phillips, M.A., D.C.L., &c., and Mr. C. Spence Bate, F.R.S., &c., who, since the meeting of the British Association at Bath in 1864, have willingly aided me in my researches in the British Fossil Crustacea.

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[1] 'Phil. Trans.,' 1858, p. 604.

[2] See Messrs. Huxley and Salter's 'Monograph,' already quoted, pp. 1—11. See also article by the writer "On the Seraphim and its Allies," in the 'Intellectual Observer,' 1863, vol. iv, p. 229.

All assistance received will, I trust, be found duly acknowledged in its proper place.

The present part forms only the first chapter of the history of the *Merostomata*, but it has been considered desirable to issue this instalment on account of the number of plates needed to illustrate the entire group, and the consequent delay caused by their preparation.

CLASSIFICATION OF THE MEROSTOMATA.[1]

I have experienced considerable difficulty in proposing a classification for this remarkable group that may appear to differ to any extent from the conclusions of the eminent zoologists who have preceded me in this work; but having the advantage not only of being able to consult and compare their published labours, but also of examining numerous specimens in a far better state of preservation than any hitherto examined or described in this country, I venture to hope that the following arrangement—with such modifications as may be deemed needful during the publication of the remaining parts of this Monograph—will be found to accord, not only with the general and detailed structure of the group and their family relationships, but also as an appropriately framed order of the great Crustacean class.

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[1] This name (derived from μηρός, *a thigh*, and στόμα, *a mouth*) was proposed by Dr. J. D. Dana in his great work on the *Crustacea* (1852) already quoted, but is adopted here for a much larger group than was contemplated by him. I prefer to enlarge a group proposed by so eminent a carcinologist, to the alternative of introducing a fresh name or the adoption of one which, though older, is inappropriate, having been founded upon an incorrect view of the structure of the fossil forms it included. (See p. 24, paragraphs 28 and 33.)

Order—MEROSTOMATA, Dana, 1852.

Having the mouth furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet and organs of prehension.

I. Sub-Order—EURYPTERIDA, Huxley, 1859.

Crustacea with numerous free thoracico-abdominal segments, the first and second (?) of which bear one or more broad lamellar appendages upon their ventral surface, the remaining segments being devoid of appendages; the anterior rings united into a carapace bearing a pair of larval eyes (*ocelli*) near the centre, and a pair of large marginal or subcentral eyes; the mouth furnished with a broad post-oral plate, or *metastoma*, and five pairs of moveable appendages, the posterior of which form great swimming feet; the telson, or terminal segment, extremely variable in form; the integument characteristically sculptured.

II. Sub-Order—XIPHOSURA, Gronovan, 1764.

Crustacea having the anterior segments welded together to form a broad, convex buckler, upon the dorsal surface of which the compound eyes and *ocelli* are placed, the former subcentrally, the latter in the centre in front; the mouth furnished with a small labrum, a rudimentary metastoma, and six pairs of moveable appendages. Posterior segments of the body more or less free, and bearing upon their ventral surfaces a series of broad lamellar appendages, the telson or terminal segment ensiform.

NOTE.—Having long been convinced of the propriety of expressing in some suitable manner the correctness of the conclusions of Professors Agassiz and James Hall as to the close affinity existing between the *Eurypterida* and the *Xiphosura*, and being fully persuaded at the same time that they naturally form two distinct, although closely related groups, I have ventured to unite them in the Order MEROSTOMATA—a name proposed by Dr. J. D. Dana for the recent King-crabs only, retaining at the same time the names *Eurypterida* and *Xiphosura*, as sub-orders; sufficient evidence for the correctness of which I trust to be able to bring forward before the completion of this Monograph.

Order—MEROSTOMATA, Dana, 1852.

I. Sub-Order—Eurypterida, Huxley, 1859.

1. *Pterygotus*, Agassiz.
2. *Slimonia*, (*Page*) H. Woodw.
3. *Stylonurus*, (*Page*) H. Woodw.
4. *Eurypterus*, Dekay.
   sub-genus *Dolichopterus*, Hall.
5. *Adelophthalmus*, Jordan,
6. *Bunodes*, Eichw.
7. *Arthropleura*, Jordan.
8. *Hemiaspis*, H. Woodw.
9. *Exapinurus*, Nieszk.
10. *Pseudoniscus*, Nieszk.

II. Sub-Order—Xiphosura, Gronovan, 1764.

1. *Belinurus*, (*König*) Baily.
2. *Prestwichia*, gen. nov.
3. *Limulus*, Müller.

These thirteen genera contain about eighty-three species, which will be found in the accompanying Tables, with their geological position and locality, and also the geographical distribution of each genus as at present ascertained.

Note.—The divisions given in the following Tables for the Devonian strata must not be supposed to represent their absolute geological succession; they are only intended to show approximately the English and Scotch equivalents for those rocks which are considered to be of Lower, Middle, or Upper Devonian age. The succession of these beds is even now undergoing revision so as to render their correlation more consistent with those of the Rhine, Belgium, and France.

TABLE SHOWING THE GEOLOGICAL RANGE AND GEOGRAPHICAL DISTRIBUTION OF THE CRUSTACEA BELONGING TO THE ORDER MEROSTOMATA.

	LOWER,			MIDDLE,			AND UPPER SILURIAN.							DEVONIAN.									
	Llandeilo.		......	Llandovery.			Wenlock.			Ludlow.													
	Lower.	Upper.	Caradoc.	Lower.	Upper.		Lower.		Upper.	Lower.		Upper.		Lower.				Middle.			Upper.		
I. PALÆOZOIC CRUSTACEA OF THE ORDER MEROSTOMATA, *Dana.* I. SUB-ORDER *EURYPTERIDA, Huxley.*	Lower Llandeilo or Arenig Beds.	Upper Llandeilo.	Bala beds with Limestone; Caradoc Sandstone, &c.	Lower Llandovery beds.	May Hill Sandstone and Pentamerus Limestone, or Upper Llandovery.	Tarannon Shale.	Woolhope Limestone and Denbighshire Grit.	Wenlock Shale.	Wenlock Limestone.	Lower Ludlow Shale.	Aymestry Limestone.	Upper Ludlow Beds (Micaceous grey sandstone).	Downton Sandstone and Passage-beds.	Sandstones and Slates of the Foreland and Linton.	Lower Sandstones of Caithness.	Arbroath Paving-stones.	Sandstones of Forfarshire and Perthshire.	Bituminous Schists of Gamrie and Caithness.	Sandstones of Torquay.	Ilfracombe Beds, N. Devon.	Petherwyn Group, Cornwall.	Pilton Group, N. Devon.	Yellow Sandstone of Dura Den.
1. Genus—PTERYGOTUS, *Ag.*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Pt. anglicus, Agassiz.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Forfarsh.	...	...	...	...	...	...	...
„ ———, (?)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Stromness	...	...	...	...	...
„ ———, (?)Eichwald	...	...	...	...	...	...	...	...	...	...	...	...	Oesel	...	...	...	...	...	...	...	...	...	...
„ *minor,* H. Woodward	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Forfarsh.	...	...	...	...	...	...	...
„ *ludensis,* Salter	...	...	...	...	...	...	...	...	...	...	...	...	Ludlow & Trimpley	...	...	...	...	...	...	...	...	...	...
„ *problematicus,* Salt.	...	...	...	...	Malvern	...	...	...	...	...	...	Ludlow	Kington	Ludlow	...	...	...	...	...	...	...	...	...
„ ————, (?)	...	...	...	...	...	...	...	Dudley	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *stylops,* Salt.	...	...	...	...	...	...	...	...	...	...	...	...	Herefordshire	...	...	...	...	...	...	...	...	...	...
„ *Banksii,* Salt.	...	...	...	...	...	...	...	...	...	...	...	Ludlow	Kington, Hereford	...	...	...	...	...	...	...	...	...	...
„ *gigas,* Salt.	...	...	...	...	...	...	...	...	...	...	...	...	Kington	...	...	...	...	...	...	...	...	...	...
„ *perornatus,* Salt.	...	...	...	...	...	...	...	...	...	...	...	...	Lanarksh	...	...	...	...	...	...	...	...	...	...
„ *bilobus,* Salt.	...	...	...	...	...	...	...	...	...	...	...	...	Lanarksh	...	...	...	...	...	...	...	...	...	...
„ *arcuatus,* Salt.	...	...	...	...	...	...	...	...	...	...	...	Leintwardine	...	...	...	...	...	...	...	...	...	...	...
„ *Cobbi,* Hall	...	...	...	...	...	...	...	...	...	...	...	...	Buffalo, U. S.	...	...	...	...	...	...	...	...	...	...
„ *macrophthalmus,* Hall.	...	...	...	...	...	...	...	...	...	...	...	...	Herkimer U. S.	...	...	...	...	...	...	...	...	...	...
„ *Osborni,* Hall	...	...	...	...	...	...	...	...	...	...	...	...	Oneida, U. S.	...	...	...	...	...	...	...	...	...	...
2. Genus—SLIMONIA, *Page.*																							
Sl. acuminata, Salt., sp.	...	...	...	...	...	...	...	...	...	...	...	...	Lanarksh	...	...	...	...	...	...	...	...	...	...
„ ? *punctata,* Salt., sp.	...	...	...	...	...	...	...	...	...	...	...	Leintwardine	...	...	...	...	...	...	...	...	...	...	...
„ *scorpioides,* Salt., MS.	...	...	...	...	...	...	...	...	...	...	...	...	Lanarksh	...	...	...	...	...	...	...	...	...	...
3. Genus—STYLONURUS, *Page*																							
St. Powriei, Page	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Pitscandly, Forfarshire	...	...	...	...	...	...	...
„ *Scoticus,* H. Woodw.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Forfarsh.	...	...	...	...	...	...	...
„ *ensiformis,* H. Woodw.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Forfarsh.	...	...	...	...	...	...	...
„ *Symondsii,* Salt., sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	Rowlestone, Herefordshire	...	...	...	...	...	...	...	...	...
„ *megalops,* Salt., sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	Ludlow	...	...	...	...	...	...	...	...	...
„ *spinipes,* Page (*Logani,* H. W.)	...	...	...	...	...	...	...	...	...	...	...	...	Lanarkshire	...	...	...	...	...	...	...	...	...	...

TABLE SHOWING THE GEOLOGICAL RANGE AND GEOGRAPHICAL DISTRIBUTION OF THE CRUSTACEA BELONGING TO THE ORDER MEROSTOMATA.
Continued.

II. PALÆOZOIC CRUSTACEA OF THE ORDER MEROSTOMATA, *Dana*. I. SUB-ORDER *EURYPTERIDA, Huxley*.	LOWER SILURIAN.	MIDDLE SILURIAN.	UPPER SILURIAN.							DEVONIAN.								CARBONIFEROUS.					
			Wenlock.			Ludlow.																	
			Lower.		Upper.	Lower.		Upper.		Lower.					Upper.			Lower.		Upper.			
			Woolhope Limestone and Denbighshire Grit.	Wenlock Shale.	Wenlock Limestone.	Lower Ludlow Shale.	Aymestry Limestone.	Upper Ludlow Beds (Micaceous grey sandstone).	Downton Sandstone and Passage-beds.	Sandstones and Slates of the Foreland and Linton.	Lower Sandstones of Caithness.	Arbroath Paving-stones.	Sandstones of Forfarshire and Perthshire.	Middle.	Petherwyn Group, Cornwall.	Pilton Group, N. Devon.	Yellow Sandstone of Dura Den, &c.	Carboniferous Limestone of Scotland, alternating with Coal-bearing Sandstones.	Carboniferous Limestone of Ireland, Wales, and South of England.	Carboniferous Rocks, Ireland.	Millstone Grit.	Coal-measures, Colebrook Dale.	South Wales Coal-measures.
4. Genus—EUYRYPTERUS, *Dekay*.	1, 2, 3	4, 5, 6	7	8	9	10	11	12	13	14	15	16	17	—	21	22	23	24	25	26	27	28	29
E. Scouleri, Hibbt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Burdie House, Fifeshire	...	...	...	...	...
„ *Scouleri* ? Hibbt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Kiltorcan Ireland	Cape Breton.	...	...	...	...	...
„ *acuminatus*, Salt.	...	...	...	...	...	...	...	...	Ludlow	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *Brewsteri*, H. Woodw.	...	...	...	...	...	...	...	...	...	...	...	Near Arbroath Forfarshire	...	...	...	...	...	...	...	...	...	...	...
„ *pygmæus*, Salt.	...	...	...	...	...	...	...	...	Kingtou, Herefords Lanarkshire	...	...		...	...	...	...	...	...	...	...	...	...	...
„ *lanceolatus*, Salt.	...	...	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *linearis*, Salt.	...	...	...	...	...	...	...	...	Kington	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *abbreviatus*, Salt.	...	...	...	...	...	...	...	...	Kington	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *chartarius*, Salt.	...	...	...	...	...	...	...	...	Lanarkshire	...	..	...	...	...	...	...	...	...	...	...	...	...	...
„ *remipes*, *Dekay*	...	...	...	...	...	...	...	...	Oneida & Herkimer Cos.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *lacustris*, Harlan	...	...	...	...	...	...	...	...	Erie, Co. NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *lacustris*, var. *robustus*, Hall	...	...	...	...	...	...	...	...	Buffalo, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *tetragonophthalmus*, Fisch	...	...	...	...	...	...	...	...	Poland & Oesel	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *cephalaspis*, M'Coy	...	...	...	...	...	...	...	...	Kendal	...	...	...	..	...	...	...	...	...	...	...	...	...	...
„ *imhofi*, Reuss, sp.	...	...	...	...	...	...	...	...	Russia ?	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *microphthalmus*, Hall ...	...	...	...	...	...	...	...	...	near Cazenovia, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *Dekayi*, Hall	...	...	...	...	...	...	...	...	Black-rock, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *pachycheirus*, Hall	...	...	...	...	...	...	...	...	Buffalo, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *pustulosus*, Hall	...	...	...	...	...	...	...	...	Buffalo, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *nanus*, Angelin...........	...	...	...	...	...	...	...	...	Gotland, Baltic	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *pulicaris*, Salt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	St. John's New Brunswk.	...	...	...	...	...	...
„ ————, sp. Salt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N. Scotia	...	...	...	...	...
4*a*. Sub-Genus—DOLICHOPTERUS, Hall.																							
D. macrocheirus, Hall	...	...	...	...	...	...	...	...	Buffalo, NewYork	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE SHOWING THE GEOLOGICAL RANGE AND GEOGRAPHICAL DISTRIBUTION OF THE CRUSTACEA BELONGING TO THE ORDER MEROSTOMATA.

Continued.

III. PALÆOZOIC CRUSTACEA OF THE ORDER MEROSTOMATA, *Dana*.	LOWER SILURIAN.	MIDDLE SILURIAN.	UPPER SILURIAN.							DEVONIAN.								CARBONIFEROUS.					
			Wenlock.			Ludlow.																	
			Lower.		Upper.	Lower.		Upper.		Lower.					Upper.			Lower.		Upper.			
I. SUB-ORDER *EURYPTERIDA, Huxley.*			Woolhope Limestone and Denbighshire Grit.	Wenlock Shale.	Wenlock Limestone.	Lower Ludlow Shale.	Aymestry Limestone.	Upper Ludlow Beds (Micaceous grey sandstone.)	Downton Sandstone and Passage-beds.	Sandstones and Slates of the Foreland and Linton.	Lower Sandstones of Caithness.	Arbroath Paving-stones.	Sandstones of Forfarshire and Perthshire.	Middle.	Petherwyn Group, Cornwall.	Pilton Group, N. Devon.	Yellow Sandstone of Dura Den.	Carboniferous Limestone of Scotland, alternating with Coal-bearing Sandstones.	Carboniferous Limestone of Ireland, Wales, and South of England.	Carboniferous Rocks, Ireland.	Millstone Grit.	Coal-measures, Colebrook Dale.	South-Wales Coal-measures.
5. Genus — **ADELOPHTHALMUS**, *Jordan.*	1, 2, 3,	4, 5, 6,	7	8	9	10	11	12	13	14	15	16	17	—	21	22	23	24	25	26	27	28	29
Ad. granosus, Jord.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Saarbruck	...
6. Genus — **HEMIASPIS**, H. Woodw.																							
H. limuloides, Salt., MS.	...	...	...	...	...	Leintwardine	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *tuberculata*, Salt.	...	...	...	...	...	Ditto	...	...	Downton	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *optata*, Salt, MS.	...	...	...	...	...	Ditto	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *sperata*, Salt., MS.	...	...	...	...	...	Ditto	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *Salweyi*, Salt., *MS.*	...	...	...	...	...	Shropshire	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
sp. nov.	...	...	...	Dudley	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7. Genus—**EXAPINURUS**.																							
Ex. Schrenkii, Nieszk.	...	...	...	...	...	...	...	...	Oesel	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8. Genus—**PSEUDONISCUS**,																							
Ps. aculeatus, Nieszk.	...	...	...	...	...	...	...	...	Oesel	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9. Genus—**BUNODES**, *Eichw.*																							
B. lunula, Eichw.	...	...	...	...	...	...	...	...	Oesel	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ *rugosus*, Nieszk.	...	...	...	...	...	...	...	...	Oesel	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10. (?) **ARTHROPLEURA**, *Jord.*																							
Ar. armata, Jordan	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Saarbruck Coalbrook Dale. Manchester	...
„ *ferox*, Salt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...
„ *mammatus*, Salt.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...
II. SUB-ORDER. *XIPHOSURA, Gronov.*																							
1. Genus—**BELINURUS**, *König.*																							
B. trilobitoides, Buckl.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Derry	...	Coalbrook Dale	...
„ *reginæ*, Baily	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Bilboa Colliery, Queen's Co.	...	...	...
„ *arcuatus*, Baily	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *Danae*, Meek & Worthen	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Illinois, U.S.	...

TABLE SHOWING THE GEOLOGICAL RANGE AND GEOGRAPHICAL DISTRIBUTION OF THE CRUSTACEA BELONGING TO THE ORDER MEROSTOMATA.

Continued.

IV. ORDER MEROSTOMATA, *Dana.* II. SUB-ORDER *XIPHOSURA.*	PRIMARY OR PALÆOZOIC.											SECONDARY OR MESOZOIC.						TERTIARY OR CAINOZOIC.	
	SILURIAN.			DEVONIAN.			CARBONIFEROUS.				PERMIAN.	TRIAS.	LIAS.	OOLITE.			CRETACEOUS.	TERTIARY.	RECENT.
														Lower.	Middle.	Upper.			
	1 to 13			14 to 23			24	—	28	29	30	31	32	33	34	35	36	37	38
2. Genus—PRESTWICHIA, gen. nov.																			
P. anthrax, Prestw, sp.	...	...	...	...	...	...	...	...	Cole-brook Dale	...	...	...	...	...	...	...	...	...	...
„ *rotundata*, Prestw., sp....	...	...	...	...	...	...	Glasgow	...	Ditto	...	...	...	...	...	...	...	...	...	...
3. Genus—? LIMULUS (*Müll.*)																			
L. ? oculatus, Kutorga	...	...	...	...	...	...	...	...	...	...	Ural Mountains	...	...	...	...	...	...	...	...
„ sp. (Schimper)...	...	...	...	...	...	...	...	...	...	...	...	Germany	...	...	...	...	...	...	...
„ ? ? *Steinlæ*, Geinitz	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Saxony	...	...
LIMULUS, *Müller.*																			
L. gigas, Münst.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Lithogr. Stone, Solenhofen	...	...	...
„ *Walchii*, Desmar.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *ornatus*, Münst.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *intermedius*, Münst.......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *brevispina*, Münst.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *brevicauda*, Münst.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *sulcatus*, Münst.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto	...	...	...
„ *Decheni*, Zincken	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	BrownCoal Sandstone, Saxony.	...
LIMULUS, *Müller.* (Living Species.)																			
„ *Moluccanus*, Latr.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Molucca.
„ *rotundicauda*, Latr.......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Do., & East Indies.
„ *longispina*, V. d. Hoev.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Japan.
„ *polyphemus*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. shores of North America.

SUMMARY OF TABLE SHOWING THE GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION OF THE MEROSTOMATA.

V. Genera.	East Indies. and Japan.	North America.	Ireland.	England.	Scotland.	Baltic Isles.	Germany.	Poland.	Russia.	Palæozoic.																							Neozoic.				
										Upper Silurian.								Devonian.								Carboniferous.						Permian.	Triassic.	Oolitic.	Cretaceous.	Tertiary.	Recent.
										5	—	8	9	10	11	12	13	14	—	16	18	19	—	22	23	24	25	26	27	28	29	30	31				
I. Eurypterida.																																					
1. Pterygotus ......16 sp.	...	3	...	7	5	1	...	...	...	1	...	1	...	...	1	3	11	1	...	2	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2. Slimonia .... 3 „	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3. Stylonurus ...... 6 „	...	...	...	2	4	...	...	...	...	...	...	...	...	...	...	...	1	2	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4. Eurypterus ......22 „	...	10	1	5	5	2	...	1	1	...	...	...	...	...	...	1	15	1	...	2	...	...	...	1	2	3	...	...	...	...	...	...	...	...	...	...	...
4*a*. *Sub-genus*—Dolichopterus ...... 1 „	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5. Adelophthalmus 1 „	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
6. Hemiaspis ...... 6 „	...	...	...	6	...	...	...	...	...	...	...	1	...	5	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7. Exapinurus ...... 1 „	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8. Pseudoniscus ... 1 „	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9. Bunodes .... 2 „	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10. Arthropleura ... 3 „	...	...	...	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	...
II. Xiphosura.																																					
1. Belinurus......... 4 „	...	1	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	...	2	...	...	...	...	...	...	...
2. Prestwichia ...... 2 „	...	...	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	2	...	...	...	...	...	...	...
3. Limulus (?)...... 2 „	...	...	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	...
„ (Limulus????) 1 „	...	...	...	...	...	...	1?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1?	...	...
„ Limulus .... 8 „	...	...	...	...	...	...	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	...	1	...
Ditto (living) 4 „	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4
Total sp.... 83	3	16	4	26	17	7	12	1	2	1	...	2	...	5	1	5	35	4	...	7	1	1	...	1	2	4	...	3	...	8	...	1	1	7	1?	1	4

BIBLIOGRAPHY

OF THE

MEROSTOMATA;*

WITH AN ACCOUNT OF THE AFFINITIES PROPOUNDED BY THE VARIOUS AUTHORS.

(*For references see p.* 20.)

1. 1809. Mr. W. Martin[1] gave a figure and short description of a Limuloid Crustacean from the Coal-measures, which he included with the *Trilobita*, and named *Entomolithus monoculites* ? (*lunatus*).

2. 1811. Mr. J. C. Parkinson[2] figured a similar fossil from the Coal-measures, Dudley.

3. 1820. Mr. Charles König[3] figured a Coal-measure *Limulus*, naming it *Belinurus bellulus*, but there is no description accompanying it.

4. We find the first notice of the discovery of *Eurypterus* in America (in 1825), by Dr. J. E. Dekay,[4] who described and figured the only species then known (*Eurypterus remipes*), and referred it to the class Crustacea, and to the order *Branchiopoda*.

5. The remains of an English species of *Eurypterus* (probably two feet in length) were described in 1831 by Dr. J. Scouler,[5] of Glasgow, under the generic name of *Eidothea*.

6. Dr. Richard Harlan[6] published the description of a second American species in 1835 (*E. lacustris*).

7. Prof. Milne-Edwards,[7] in 1834-36, observes, with respect to the genus *Eurypterus*, established by Dekay, "They have externally many points of resemblance to *Pontia* and *Cyclops*, and they also seem to indicate, in some respects, a passage between these animals and the *Isopoda*. The body is broad and more or less pyriform, and the head very distinct from the thorax, which is divided into many segments, but is not separated by any marked distinction from the abdomen. The head bears on its superior surface two reniform eyes, well developed, and distant from each other. Two pairs of antennæ have also been distinguished; and whatever other appendages there may be, appertain to the mouth. Lastly, on each side of the first thoracic ring one sees a great lamelliform swimming-foot, with a rounded termination."

"Geologists," M. Milne-Edwards adds, "describe three species of *Eurypterus*, viz., *E. remipes*, Dekay, *E. lacustris*, Harlan, and *E. Scouleri*, Hibbert."

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* Should any omissions be discovered in this history, I shall feel obliged to palæontologists who will call my attention to them, that they may be inserted in the future parts of this Monograph.—H. W.

The *Eurypteridæ* are placed by Prof. Milne-Edwards at the end of the order *Cyproidea* or *Ostracoda.*

8. Dr. S. Hibbert[9] in 1836 referred the crustacean remains described by Dr. Scouler under the name *Eidothea* (¶ 5) to the genus *Eurypterus*, with the specific name of *Scouleri.*

9. The Rev. Dr. Buckland,[10] in 1836, described a fossil *Limulus* from Coalbrook Dale, under the name of *L. trilobitoides.*

10. In 1838 Dr. S. Kutorga[11] described and figured a head-shield of *Limulus* from the Permian formation of the western slopes of the Ural Mountains (Government of Perm), under the name of *L. oculatus.*

11. In 1838 Prof. Milne-Edwards[12] took the opportunity to examine the eggs of *Limulus* containing the young ones about to be hatched; he found that at this stage of their development they present very little difference in the conformation of the anterior portion of their body from that which exists in the adult; but the abdominal portion of the body bears only three pairs of appendages, and the long styliform tail (telson), so remarkable in the adult, does not exist at all; the form of the abdominal portion likewise is equally different at this epoch.

12. M. J. van der Hoeven,[13] in 1838, gave an anatomical description of *Limulus,* and described four living and six fossil (Oolitic) species; the latter are all from Solenhofen.

13. M. G. Fischer de Waldheim[15] described a new species of *Eurypterus* from Russian Podolia, under the name of *E. tetragonophthalmus*, in 1839.

14. In 1840 Mr. J. Prestwich[16] described and figured two new species of fossil *Limuli*, *L. anthrax* and *L. rotundatus*, from the clay-ironstone of Colebrook Dale Coal-field.

15. In 1840 Count Münster[17] figured and described a fragment of a very large *Limulus* from the Solenhofen Slate of Bavaria, naming it *Limulus giganteus.*

16. In 1841 Münster[18] described and figured an imperfect specimen under the name of *Limulus priscus*, which has since been referred by H. von Meyer to his genus *Halicyne.* The specimen is from the Muschelkalk of Wurtemberg.

17. In 1841 Mr. Conrad,[19] in New York, notices a single American specimen of *Eurypterus* (*E. remipes*), which he says when perfect had a long spiniform tail, like *Limulus*, but more obtuse and finely serrated.

18. In 1843 Mr. Vanuxen[20] figured a head and first articulation of *E. remipes*, but added no new facts.

19. In the same year General Portlock[21] figures a specimen said to be from the Carboniferous Shale ("most probably, however, Coal-measures," *Baily*), Maghera, County Derry, doubtfully referred to *L. trilobitoides.*

20. Some fragments of a fossil—supposed at the time to be parts of fishes—were figured by Prof. L. Agassiz[23] (1844), from the Old Red Sandstone of Forfarshire. "Deceived by the scaly aspect of a portion of the carapace, I at first," says Prof. Agassiz,

"believed that this might be the type of a peculiar genus of fishes, and to that class I referred *Pterygotus* in my enumeration of the fossil fishes of the Silurian system, published in Murchison's great work"[14] (1839). The discovery of more perfect remains in Scotland convinced Agassiz that they must be Crustacea. He adds, "I am rather inclined to believe that this singular animal will become the type of a family intermediate between the *Trilobites* and the *Entomostraca*, in which, perhaps, the *Eurypteri* and the *Eidotheæ* will some day be included."

21. 1845. The REV. P. B. BRODIE, M.A., F.G.S.,[23] in his 'History of Fossil Insects,' describes and figures a curious fossil in clay-ironstone from Coalbrook-dale resembling the Caterpillar of the Emperor Moth (*Saturnia pavonia-minor*). This has since been described (1863) by Mr. J. W. Salter, as *Eurypterus* (*Arthropleura*) *ferox*.

22. Dr. H. BURMEISTER,[24] in his systematic arrangement of Trilobites, &c. (1846), makes the *Eurypteridæ* the first family of the tribe *Palæadæ*, which, he observes, are "characterised by the possession of two large compound eyes, by the absence of secondary eyes, and by having short undeveloped feelers and soft leaf-formed feet, bearing gills," &c. Of the *Eurypteridæ* he says, "In these there is no shell. The head, whose position is very distinct, bears two pairs of setaceous feelers and one pair of accessory parts of the mouth. There are probably nine (?) rings in the thorax, the first of which bears a pair of very large rudder-shaped feet, furnished with five joints, and the succeeding rings seem to have borne similar leaf-like feet of an equal size. The abdomen consisted of three or six rings, and was terminated by a pair of rudder-fins (?)."

23. 1847. HUGH MILLER[25] gives an interesting description of Agassiz's first examination of the remains of *Pterygotus* in Mr. Webster's collection from Balruddery; and he figures a portion of a foot-jaw (supposed at that time to be a tail-lobe).

24. In 1850 Dr. H. B. GEINITZ[28] figures and describes a fossil remain from the Chalk formation (Lower Pläner) of Plauen in Saxony, which he names *Limulus Steinlæ*. Not having seen the original specimen, we should hesitate to deny its crustacean character; but we see no evidence of its affinity to *Limulus*, judging from the figure given.

25. Dr. FERDINAND ROEMER,[29] in 1851, gave a notice of *Eurypterus*, in which he suggested the affinity of that genus with *Limulus*; pointing out, however, the great difference in the feet, &c.

26. Mr. J. W. SALTER,[30] in 1852, figured and described two fragments of the chelate appendages of *Pterygotus problematicus*, Agassiz, from the Upper Ludlow Rock, Herefordshire.

27. M. ED. VON EICHWALD,[31] in 1854, gives figures of *Eurypterus tetragonophthalmus* of Fischer, which—as Mr. James Hall has pointed out—he erroneously ascribes to *E. remipes* of Dekay. He also figures a perfect segment of *Pterygotus*, which he ascribes to *Pt. Anglicus*, Ag. He considers that *Eurypterus* and *Pterygotus* were very closely allied genera. M. von Eichwald's specimens are from the Island of Œsel, in the Baltic.

28. Prof. F. M'Coy, in 1849,[26] and again in 1854,[33] thus classifies this group—"Ord. Entomostraca, Trib. *Pœcilopoda.* This group being distinguished from other Entomostraca by having crustaceous, didactyle, ambulatory, thoracic feet, as well as membranous, respiratory, abdominal ones, is, I think, clearly the place for those remarkable genera *Eurypterus* and *Pterygotus.*" He adds further, "The tribe *Pœcilopoda* might be resolved into two families—1st, *Limulidæ—Limulus;* 2nd, *Eurypteridæ—Eurypterus, Pterygotus, Bellinurus.*

29. Prof. M'Coy[35] also figures and describes the head of *Eurypterus cephalaspis,* from Kendal (Pl. I E, fig. 21), a somewhat doubtful form. His *Pterygotus leptodactylus* is founded on the tail-spines of *Ceratiocaris,* as pointed out by Mr. Salter.

Like Dr. Hibbert,[9] he attributes to Dr. Harlan (1835) the genus *Eurypterus,* which was established by Dr. J. E. Dekay[4] in 1825.

30. Prof. F. J. Pictet[34] (1854) places *Eurypterus* with the *Copepoda,* adopting Burmeister's[24] description. In the *Xiphosura* he places *Limulus, Halycine, Bellinurus,* and *Pterygotus.*

31. In Prof. Owen's 'Lectures'[36] (1855) we find the order *Xiphosura* placed in the sub-class *Entomostraca,* along with the orders *Trilobita* and *Phyllopoda.*

32. Prof. A. E. Reuss,[37] in 1855, gives a description of what he considers to be a new genus of Eurypterids, from the Coal Shale of Bohemia, preserved in the Prague Museum. He names it *Lepidoderma Imhoffi,* but it is certainly a *Eurypterus,* judging, not only from his beautiful plates, but also from a cast sent to us by Dr. Anton Fritsch.

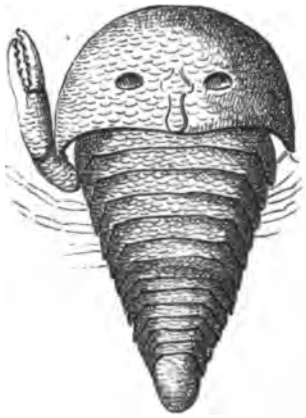

Fig. 3. *Pterygotus problematicus,* Agassiz [copied from Prof. M'Coy's figure in Lyell's 'Manual of Geology,' 1855 (5th edition).]

33. Prof. M'Coy again, in 1855,[35] furnishes us with a classification and descriptions of species of this group; and in Sir Charles Lyell's Manual[38] he gives a restoration of *Pterygotus problematicus,* where he again expresses his belief in the close alliance of *Pterygotus* and *Eurypterus,* and of both these to the living King-crab, or *Limulus.*

34. In the same year Mr. David Page[39] named various species, and offered a restoration of *Pterygotus.* He observed that "The *Pterygotus* could be classed with no

living family, and was in aspect more like the larvæ than the adult forms of any Crustacean with which we are acquainted."

35. Later in the same year Sir R. I. MURCHISON[40] gave an account of the discovery, by Mr. Robert Slimon, of a remarkable series of Pterygotian remains at Lesmahago, Lanarkshire, in which he observes that the uppermost Silurian Strata in Russia, in England, and in North America, are characterised by the presence of *Pterygotus* and *Eurypterus*, associated with small *Lingulæ* and other fossils.

36. 1856. Mr. J. W. SALTER[41] follows with a description and figures of a new genus of *Pterygoti*, viz. *Himantopterus*, of which he there gives notice of six species, namely, *H. maximus* and *acuminatus* (now united in *Slimonia acuminata*), *H. bilobus*, *H, perornatus*, *H. Banksii* (now referred to *Pterygotus*) and *H. lanceolatus* (since referred to *Eurypterus*).

37. 1856. Prof. T. H. HUXLEY[42] adds some observations on the structure and affinities of *Himantopterus*. The conclusion he draws is that "The nearest approach to *Himantopterus* which could be constructed out of the elements afforded by existing Crustacea would be produced by superinducing, upon the general form of a Cumoid Crustacean, such a modification of the appendages as we find among the Zoæform Macruran larvæ." In fact, that *Himantopterus* bears a strong similarity to a larval form, but is not itself therefore to be considered embryonic.

38. In 1856 Dr. H. JORDAN and HERMANN VON MEYER[43] described a curious (blind) Crustacean from the Culm-formation of Saarbruck under the name of *Adelophthalmus* (*Eurypterus*) *granosus*, Jord.; also the fragment of a second remarkable form which is named *Arthropleura armata*, Jord.

39. 1856. Mr. DAVID PAGE[45] gives figures of *Pterygotus*, *Himantopterus*, *Stylonurus*, and *Slimonia*, and observes, "Respecting these Crustaceans, their place is altogether unknown in zoology, there being, as it were, an interfusion of phyllopod, pœcilopod, and decapod,—of brachyurous, macrourous, and xiphosurous forms."

40. In Prof. T. H. HUXLEY'S[46] 'Lectures on Natural History,' published November 7th, 1857, appears the following description of the *Eurypterida*:—"This group includes the Devonian and Silurian genera *Eurypterus* and *Pterygotus*, which, though as little embryonic in their characters as the *Trilobita*, are, in many respects, curiously larval. These singular Crustaceans attained a very great size, species of *Pterygotus* of several feet in length being known. The body, in those forms which have been most carefully examined, consists of a comparatively small carapace, rounded anteriorly, and carrying on its upper surface a pair of elevations, which are distant in *Pterygotus* and approximate in *Eurypterus*, and were, in all probability, the eyes.

"Ten to twelve distinct segments succeed the carapace, becoming narrower posteriorly to the last, varying in shape from lanceolate to oval, and deeply emarginate, probably represented a telson.

"Three pairs of appendages were attached to the carapace in *Pterygotus*—anterior pincer-like antennæ; median toothed mandibles, provided with a large palp; and a pair of posterior long gnathites, with a large toothed coxopodite, succeeded by a number of joints, the last of which has the form of an oval palette. These last members probably performed the function of locomotive or swimming feet. A considerable epistomial region lies in front of the mouth, as in *Limulus*, and a large oval plate, emarginate anteriorly, covered the mouth in the median line.

"No limbs have been found in connection with the abdominal somites, nor have any detached parts different from those just described been as yet discovered. Many parts of the surface of the body and of the appendages exhibit an exceedingly peculiar structure, resembling the conventional representation of feathers, or the mode in which they are represented in the Assyrian and Egyptian sculptures; and it was from this cause, apparently, that the Scotch quarrymen conferred the title of 'Seraphim' upon the *Pterygotus*.

"The *Diastylidæ* are the only *Crustacea* with which I am acquainted which exhibit anything similar to this ornamentation; and in the number of free somites, and the more or less rudimentary condition of the abdominal appendages, this aberrant group of *Podophthalmia* presents other analogies with the *Eurypterida*. The carapace, the prehensile antennæ, the largely developed posterior gnathites of *Pterygotus*, are to be paralleled among the *Copepoda* and *Xiphosura*, from which, however, and indeed from all other adult *Crustacea* with which I am acquainted, the *Eurypterida* differ widely in certain other respects.

"The absence of developed posterior thoracic and abdominal members in a Crustacean possessing the corresponding somites is to be met with, in fact, only among the Zoæiform larvæ of the *Macrura* and *Brachyura*, in which, as we have seen, the proportions of the body are not dissimilar to those of the *Eurypterida*, where the abdominal appendages are entirely absent, and the well-developed and conspicuous thoracic and cephalic members are not more than two or three pairs in number, and consist of antennæ and maxillipedes, the latter serving as locomotive organs.

"I conceive, therefore, that the *Eurypterida* must form a group by themselves, which are best understood by combining together organic peculiarities at present found only in the *Copepoda*, the *Xiphosura*, the *Diastylidæ*, and the larvæ of *Podophthalmia*."

41. In June, 1858,[47] Mr. J. W. SALTER communicated to the Geological Society descriptions and figures of six new species of *Eurypterus*, and gave an account of the distribution of the group.

42. On the 22nd January, 1859,[48] appeared Messrs. HUXLEY and SALTER's grand Monograph 'On the Anatomy and Affinities of the Genus *Pterygotus*,' with descriptions of twelve species (pp. 105, 8vo, and sixteen folio plates).*

43. In the same year a Russian naturalist, Dr. JOHANNES NIESZKOWSKI,† published

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* This standard work will necessarily be so frequently referred to in the pages of this Monograph, that it would be superfluous to give a mere extract from it here. Its authors are quoted in clauses 26, 36, 37, 40, 41, 45, 51, and 57.

† Dr. Nieszkowski's paper is referred to by Mr. Salter, 'Quart. Journ. Geol. Soc.,' 1863, vol. xix, p. 81; but the author's name is misprinted Wieskowski.

a paper, which he had read in October, 1858, to the Dorpat Naturalists' Society[49] on *Eurypterus remipes* from the Upper Silurian strata of the Island of Oesel, Baltic. Dr. Nieszkowski gives restorations of the upper and under sides of *Eurypterus;* and in the latter figure he shows the appendages of the mouth *in situ*, and *three* thoracic plates for the under side of the body. We think this possibly arises from a misconception of the median appendage, but shall refer to this paper again when treating of the genus *Eurypterus.*

44. In a second paper communicated to this society, in October, 1858, Dr. NIESZKOWSKI[50] describes and figures *Bunodes lunula* of Eichwald, and a new species, which he names *B. rugosus;* also two new genera allied to *Hemiaspis*, namely, *Exapinurus Schrenkii*, and *Pseudoniscus aculeatus;* all these are from the Upper Silurian of Rootziküll, Island of Oesel, Baltic. He has likewise figured a metastoma or lip-plate of *Pterygotus*, four inches in length and three inches broad, from the same locality.

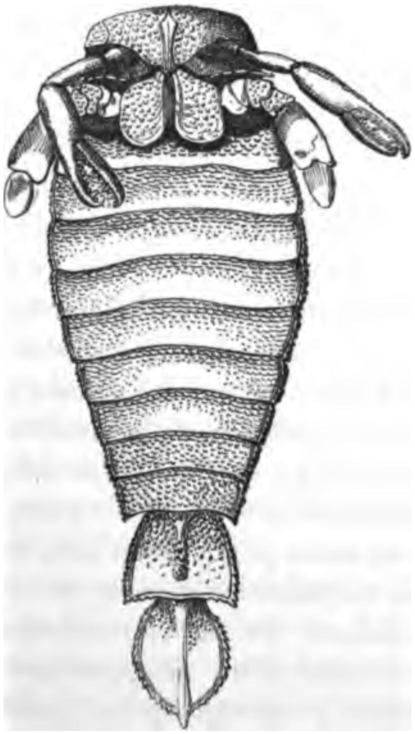

FIG 4. *Pterygotus anglicus*, Agassiz, restored (1859).

45. The third (second) edition[51] of Sir R. I. MURCHISON'S 'Siluria' (1859) furnishes us (besides numerous separate notices of the *Eurypterida*) with a restored figure, by Mr. J. W. Salter, of *Pterygotus anglicus*, about one twentieth natural size, giving all the details then known.

46. Mr. DAVID PAGE[52] gives us (1859) restorations of *Pterygotus anglicus*, *Himantopterus acuminatus*, *Stylonurus Powriei*, *Stylonurus spinipes*, *Eurypterus clavipes*, *Euryp-*

terus Scouleri, and *Limulus rotundatus*, all more or less correct. He repeats most of his former views, and makes some critical remarks upon Mr. Salter's restoration, as given in 'Siluria,' which, however, he reproduces.

47. At the close of 1859 Prof. JAMES HALL,[53] Geologist for the State of New York, in his 'Report on the Palæontology of New York,' gives a very excellent account of *Eurypterus*, with many figures of the actual fossils and restorations of the genus, also figures of the more rare American species of *Pterygoti*. Frequent reference will be made to Prof. Hall's work in the course of this Monograph.

48. Mr. W. H. BAILY[54] describes (1859) some new forms of *Limuli* from the Coal-measures, for which he proposes the names *Belinurus reginæ* and *B. arcuatus*; they were found in the Bilboa Colliery, Queen's County, Ireland.

49. In 1862 Mr. C. GIEBEL[55] describes a *Limulus*, which he names *L. Decheni*, from the Braunkohlen-Sandstein near Teuchern, Prov. Saxony.

50. 1862. Prof. JAMES HALL[56] figures the carapace of what may possibly be, as he suggests, the shield of a *Limulus*-like Crustacean in the Potsdam Sandstone, Black River, Wisconsin. It has, however, somewhat more the aspect of a crushed Trilobite shield than the head of a *Limulus*.

51. In May, 1862, Mr. J. W. SALTER communicated to the Geological Society of London[57] descriptions and figures of some species of *Eurypterus* and allied forms, and he there makes the following remarks upon *Pterygotus*, &c.:

"Since the appearance, in 1859, of the Memoir by Prof. Huxley and myself on *Pterygotus* and its allies, the great work of Prof. Hall, of Albany, has appeared ('Palæontology of New York,' vol. iii), containing the fullest material for the illustration of this genus; and following, as it did, upon the very full account given by Dr. Wieskowski,* it has completed our knowledge of the structure of this remarkable genus. And there seems to be now no doubt whatever that the anomalous plates and processes,† about the position of which Prof. Huxley and myself were compelled to guess, and which for many obvious reasons were compared with the under portion of the head, really belong to the under part of the thorax. All this was as satisfactorily made out by the Russian author as by Prof. Hall's independent researches. We had also arrived at the same conclusion before Wieskowski's* admirable paper reached us. For, previous to the Meeting of the British Association at Aberdeen, in 1859, I was sent by the Director-General of the Geological Survey to examine the collections made by Mr. Slimon, of Lesmahago; and in that fine series (which was sent to the Meeting for exhibition) we found abundant proofs of the true position of the sternal plates, such as Wieskowski* and Hall have figured, and of the place of the post-oral plate, previously assigned by Prof. Huxley to the hinder margin of the mouth. The position of the chelæ in these new specimens also confirmed the Professor's judgment in assigning them to the antennæ or antennules; and they supported my own view, too, as to the existence of three pairs of appendages to the head, exclusive of the chelæ and the large swimming-feet, which are also, as we learn from the new and more perfect specimens found, both in America and Russia, included with the appendages of the mouth.

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* *For* Wieskowski *read* Nieszkowski. See Ante, p. 26, ¶ 43.

† The thoracic plate, or operculum.

"The chief new points, I take it, in Prof. Hall's beautiful series are, first, the larger number of joints in the great maxillary appendages than was supposed from analogy with *Pterygotus*, where there are certainly only seven; and, secondly, the existence of ocelli on the dorsal surface of the shield, such as give it a wonderfully Limuloid aspect. But some of the *Copepoda* have similar ocelli; and as to the affinities, it would be out of place in every way to give my opinions when the naturalist is by who first truly studied these relations. Whatever corrections better specimens may have led to, the main credit is due to him who from fragmentary materials constructed a true hypothesis."

Mr. Salter describes[57] *E. pulicaris* from the Devonian of St. John's, New Brunswick; a fragment of a species allied to *E. Scouleri*, from the Coal-measures, Port Hood, Cape Breton; part of the telson of a *Eurypterus* (?) from Coal-measures, Nova Scotia.

He also gives[57] a fresh description (without a figure) of *E. Scouleri*, Hibbert, and figures and describes *E.* (*Arthropleura ?*) *mammatus* and *E.* (*Arthropleura*) *ferox*, the first from Kirkton, Bathgate; the second from Pendleton Colliery, near Manchester; the third from the (Penny-stone ?) Ironstone, Coal-measures, North Staffordshire.

52. 1863. Mr. W. H. BAILY[58] gives a more complete account of the new *Limuli* from the Irish Coal-measures, and good figures of *Belinurus reginæ* and *B. arcuatus.*

53. In November, 1863,[59] a notice appeared by the author, with figures, of *Slimonia* (*Pterygotus*) *acuminata*, in which he showed the propriety of placing this species in a distinct genus (as proposed by Mr. David Page), and pointed out many important characters by which it is at once separable from *Pterygotus.*

54. In 1864 the author described and figured[60] *Eurypterus lanceolatus*, Salter, from Lanarkshire, only imperfectly known before.

55. In the same year he exhibited specimens and restored figures of *Stylonurus, Pterygotus, Slimonia, Eurypterus,* and *Hemiaspis*, before the British Association,[63] Bath; and in November he published[61] descriptions and figures of *Stylonurus Logani, Styl. ensiformis, Eurypterus Brewsteri,* and *Pterygotus minor*, and likewise gave a list of all the then known British species, with localities.[61]

56. In 1865 Sir CHARLES LYELL[64] published an amended figure of *Pterygotus Anglicus*, to supersede that which had been designed by Prof. M'Coy.

57. In November of the same year the Geological Society[65] published the author's descriptions of *Stylonurus Scoticus* and *Stylonurus Powriei* from the Devonian of Forfarshire, and *Hemiaspis limuloides* from the Lower Ludlow Rock, Leintwardine.

REFERENCES.

1 1809. Martin, W.—Petrificata Derbiensis, 4to, t. 45, fig. 4.

2 1811. Parkinson, J. C.—Organic Remains of a Former World, 4to, vol. iii, p.* 267, pl. xvii, fig. 18.

3 1820. König, Icones Fossilium Sectiles: Centuria Seconda; pl. xviii, fig. 230.

4 1825. Dekay, Dr. J. E.—Ann. of the Lyceum of Nat. Hist. of New York, p. 375, pl. xix.

5 1831. Scouler, Dr. J.—Cheek's Edinburgh Journ. of Nat. and Geograph. Science, vol. iii, p. 352, t. x.

6 1835. Harlan, Dr. Richard.—Medical and Physical Researches, Philadelphia, p. 297; see also Transactions Geol. Soc. Pennsylvania, vol. i, p. 96.

7 1834-6. Milne-.Edwards, Prof. H.—Hist. Nat. des Crustacés, 3 vols., Paris, vol. iii, p. 422.

8 1835. Bronn, H. G.—Lethæa Geognostica, p. 109, t. 9, figs. 1 and 2 (figures of *E. remipes* and *E. Scouleri*); no additional information given.

9 1836. Hibbert, Dr. S.—Trans. Roy. Soc. Edinburgh, vol. xiii, p. 280, pl. xii.

10 1836. Buckland, Rev. W.—Geology and Mineralogy, &c. (one of the Bridgewater Treatises), vol. i, p. 396; vol. ii, p. 77, pl. 46″, fig. 3.

11 1838. Kutorga, Dr. S.—Beitrag zur Kenntn. der Organ. Ueber. des Kupfersand. am Westl. Abhange des Urals. St. Petersburg, 8vo, p. 22, tab. iv, figs. 1—3.

12 1838. Milne-Edwards, Prof. H.—Sur le Développement des Limules; Société Philomatique, Nov. 10.

13 1838. Hoeven, J. van der.—Recherches sur l'Histoire Naturelle et l'Anatomie des Limules. Leyden, 4to, 1838, pp. 48, 7 plates.

14 1839. Murchison, Sir R. I.—Silurian System, 4to. Notes by Prof. Agassiz, chap. xlv, p. 605, figs. 4—6.

15 1839. Fischer de Waldheim, G.—Bulletin de la Soc. Impér. des Natural. Moscou, vol. ii, pp. 125—128.

16 1840. Prestwich, J.—Trans. Geol. Soc. Lond., 2nd ser., vol. v, t. xli, figs. 1—8.

17 1840. Münster, G.—Beiträge zur Petrefacten-Kunde. Bayreuth, 4to, Heft iii, p. 26, taf. i, fig. 9.

18 1841. Münster, G.—Beiträge zur Geogn. und Petref., &c. Bayreuth, 4to, p. 71, taf. v, fig. 1.

19 1841. Conrad.—Annual Report on the Palæontology of New York, p. 38.

20 1843. Vanuxem.—Geol. Rep. Third District of New York.

21 1843. Portlock, J. E.—Rep. on Geol. of County of Londonderry, &c. Dublin, 8vo, p. 316, pl. xxiv, fig. 11.

22 1844. Agassiz, L.—Mon. des Poissons Foss. du Vieux Grès Rouge, ou Syst. Dévonien. Neufchatel, folio plates, 4to text, page xix.

23 1845. Brodie, Rev. P. B.—Hist. of Fossil Insects in the Secondary Rocks of England. Introduction, p. xvii, pp. 105, 115, pl. i, fig. 11. 'Caterpillar?' (*Eurypterus* (*Arthropleura*) *ferox*, Salt).

24 1846. Burmeister, Hermann.—The Organization of Trilobites, 4to (Ray Society, London), p. 53.

25 1847. Miller, Hugh.—"The Old Red Sandstone." Edinburgh, 3rd edition, 16mo, pp. 182 and 183, pl. ix.

26 1849. M'Coy, Prof. Frederick.—Ann. and Mag. Nat. Hist., 2nd. ser., vol. iv, pp. 393, 394.

27 1850-56.—Bronn, H. G., and Roemer, F.—Lethæa, pl. ix, figs. 1 and 2, and pl. ix^{3}, being a figure of *E. lacustris*, Harlan.

28 1850. Geinitz, Dr. H. B.—Charakteristik der Schichten und Petrefacten des sachsisch-böhmischen Kreidegebirges, &c. Leipzig, 8vo, pt. 4, p. 6, tab. iv, fig. 5.

29 1851 Roemer, Dr. Ferd.—Dunker und Meyer's Palæontographica. Cassel, 4to, p. 190, t. xxvii.

30 1852. Salter, J. W.—Quart. Journ. Geol. Soc. Lond., vol. viii, p. 386, pl. xxi, figs. 1 and 2.

31 1854. Eichwald, Edw. von.—Bulletin de la Soc. Imp. des Naturalistes de Moscou, tome xxvii, p. 100, tab. i and ii, fig. 5.

32 1854. Morris, Prof. John.—Catalogue of British Fossils. London, 2nd edition, 8vo. *Eurypterus* (3 species), p. 108; *Leptocheles* (2 species), p. 110; *Pterygotus* (2 species), p. 114.

33 1854. M'Coy, Prof. F.—Contrib. to Brit. Palæont. (republished from the Ann. and Mag. Nat. Hist., 1849). Cambridge, 8vo, pp. 139—141.

34 1854. Pictet, F. J.—Traité de Paléontologie. Paris, 2nd edition, tom. ii, p. 529 and pp. 536—539.

35 1855. Sedgwick and M'Coy.—British Palæozoic Rocks and Fossils, 4to, p. 174, pl. i e, fig. 21.

36 1855. Owen, Prof. R.—Lectures on Comparative Anatomy—*Invertebrata*—Royal Coll. Surgeons London, 2nd edition, pp. 309, 315, 331, and 343.

37 1855. Reuss, Prof. A. E.—Denksch. der K. Akad. der Wissensch. Wien, 4to, Band x, pp. 81—83, taf. iii and iv.

38 1855. Lyell, Sir Charles.—A Manual of Elementary Geology. London, 8vo, pp. 419 and 420, figs. 542 and 543. (Restoration of *Pterygotus*, by Prof. M'Coy.)

39 1856. Page, David.—Rep. British Association, Glasgow, 1855, Trans. of the Sections, pp. 89—91.

40 1856. Murchison, Sir R. I.—On the Lesmahago Silurians, and the Discovery of Fossils in the Uppermost Silurian rocks of Lanark. Quart. Journ. Geol. Soc., vol. xii, pp. 15 to 25.

41 1856. Salter, J. W.—On some new Crustacea from the Uppermost Silurian Rocks, op. cit., pp. 26—34, figs. 1—7.

42 1856. Huxley, Prof. T. H.—Observations on the Structure and Affinities of *Himantopterus*, op. cit., pp. 34—37.

43 1856. Jordan, Dr. H., and H. von Meyer.—On the Crustacea of the Stone-coal of Saarbruck. 'Palæontographica,' Band iv, pp. 8—15, tab. ii, figs. 1, 4, and 5.

44 1856. Banks, R. W.—On the Tilestones, or Downton Sandstones, near Kington, Hereford. Quart. Journ. Geol. Soc., vol. xii, p. 99, pl. ii, figs. 4—6.

45 1856. Page, David.—Advanced Text-Book of Geology, 1st edition, 8vo, pp. 128 and 135.

46 1857. Huxley, Prof. T. H.—Lectures on General Natural History. Medical Times and Gazette, vol. xxxvi, lecture xiii, p. 470.

47 1859. Salter, J. W.—Quart. Journ. Geol. Soc., vol. xv, p. 229—236, pl. x.

48 1859. Huxley, T. H., and Salter, J. W.—"On the Anatomy and Affinities of *Pterygotus*." Monograph I, Mem. Geol. Surv. of the United Kingdom, 8vo, pp. 105, with 16 folio plates.

49 1859. Nieszkowski, Dr. Johannes.—Archiv für die Naturkunde Liv.- Ehst.- und Kurlands, Erste Ser., vol. ii, p. 299, pl. i and ii. Dorpat.

50 1859. Nieszkowski, Dr. J.—Op. cit., pp. 378—383, tab. i, fig. 19, tab. ii, figs. 12—15.

[51] 1859. Murchison, Sir R. I.—Siluria (3rd edition), notes and figures of *Pterygotus*, *Eurypterus*, and *Limulus*, pp. 140, 149, 155, 156, 178, 263—266, 274, 312, 319, 380, 539, 567.

[52] 1859. Page, David.—Advanced Text-Book of Geology, 2nd edition, pp. 163, 171, 172, 181, and 189.

[53] 1859. Hall, Prof. James, LL.D.—Natural History of New York, Part VI, Palæontology, vol. iii, 4to, plates 80 and 80*a*, 81 and 81*a*, 81*b*, 81*c*, 82, and lxxxii, 83 and 83*a*, 83*b* and 84*a*, pp. 382 to 419*.

[54] 1859. Baily, W. H.—Explanation of Sheet No. 137 of the Maps of the Geological Survey of Ireland. Dublin, pp. 12—14.

[55] 1862. Giebel, Prof. C.—Zeitschrift für die ges. Naturw., p. 329, and Leonhard und Geinitz, Neues Jahrbuch, 1863, p. 249.

[56] 1862. Hall, Prof. James, LL.D.—Canadian Naturalist, 31st October; see also Geologist, 1863, July, vol. vi, p. 247.

[57] 1863. Salter, J. W.—Quart. Journ. Geol. Soc., vol. xix. British North American Crustacea, p. 78. British Crustacea, pp. 81—87.

[58] 1863. Baily, W. H.—Ann. and Mag. Nat. Hist., series 3rd, vol. xi, pp. 107—114, pl. v.

[59] 1863. Woodward, Henry.—Intellectual Observer, vol. iv, p. 229 (with a plate).

[60] 1864. Woodward, Henry.—Geological Magazine, vol. i, p. 107, pl. 5, figs. 7—9. On *Eurypterus lanceolatus*.

[61] 1864. Woodward, Henry.—Geological Magazine, vol. i, p. 196, pl. x, and p. 239.

[62] 1865. Page, David.—Handbook of Geological Terms, 2nd edition, pp. 39, 195, 376, and 422.

[63] 1865. Woodward, Henry.—British Association Reports for 1864, Transactions of Sections.

[64] 1865. Lyell, Sir Charles, Bart.—Sixth edition of Elements of Geology, p. 524, fig. 591. Restoration of *Pterogytus anglicus*, by H. Woodward.

[65] 1865. Woodward, Henry.—Quart. Journ. Geol. Soc., vol. xxi, p. 482, pls. xiii and xiv.

Order—MEROSTOMATA, *Dana.*

Sub-Order—Eurypterida, *Huxley.*

Genus 1.—Pterygotus, *Agassiz,* 1844.

Although *Eurypterus* was the first-discovered genus of this sub-order, both in this country and also in America, as we have seen by the foregoing history, I have nevertheless preferred to commence this Monograph with the genus *Pterygotus,* as having become historically the most important in England; its affinities having been studied and its structure described by such distinguished naturalists and palæontologists as Messrs. Agassiz, McCoy, Salter, Huxley, and Hall.

The genus *Pterygotus* not only contains the largest species of the whole order, and probably of the whole Crustacean class, but the remains of several of the species are exceedingly perfect and complete. Even the great *Pterygotus anglicus,* which forms the subject of this chapter, once only known by a few gigantic fragments, is now capable of restoration from almost entire specimens figured in the accompanying plates.

For the discovery and preservation of these very perfect remains we are indebted to the accurate geological knowledge and untiring exertions of Mr. James Powrie, F.G.S., of Reswallie, Forfar, who during many years has not only encouraged the quarrymen to preserve the organic remains from the "Arbroath paving-stone" and overlying shales, but has also personally worked in the quarries of the district for days and weeks together to procure specimens.

No higher testimony can be afforded as to the value of my friend's labours than by referring to the accompanying plates, the materials for which were nearly all furnished by his own museum, those figured from the British Museum having likewise been procured and presented by him.

The great "Seraphim" of the Scotch quarrymen, *Pterygotus anglicus* of Agassiz,[1] was the first species described[2] (1844), and is now very well represented, not only in detail, by numerous detached organs and parts of bodies, but also by four nearly entire bodies of various sizes.

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[1] See Bibliography, p. 22, ¶ 20.

[2] In Murchison's 'Silurian System' (1839), p. 606, pl. iv, figs. 4 and 5, two fragments of *Pterygotus* are figured and described by Prof. Agassiz under the name of *Sphagodus pristodontus;* these have since been referred by Mr. Salter (Mem. Geol. Survey, Mon. I, p. 89) to *P. problematicus,* Ag.

The largest of these measures about four feet in length and some fifteen inches in breadth,[1] and is preserved in the Arbroath Museum, having been presented to that institution by Lord Dalhousie. It was obtained from his lordship's quarries at Carmyllie, in Forfarshire.

The specimen is preserved as an intaglio upon a large slab of Devonian sandstone, into which the detached body fits, as into a mould, exhibiting both the upper and under surfaces of eight of the body-segments united together. The head is wanting, but a portion of the base of a foot-jaw (maxillipede) belonging to the right side remains; the operculum or thoracic plate is also partially preserved.

The next largest example is from the Turin Hill Quarries, Forfarshire, and was presented to the British Museum by James Powrie, Esq., F.G.S. It is but very slightly distorted, and exhibits the natural rounded form of the dorsal surface of the body in an admirable manner. Ten of the body-rings are preserved united, measuring twenty-seven inches in length by about ten inches across the widest segment.

The third, which is figured on Pl. I, fig. 1, is twenty-three inches in length and seven inches in its greatest breadth; it was obtained from the same locality as the one last before mentioned. In this specimen the ventral surface is exposed to view, exhibiting the metastoma or post-oral plate (*p*), preserved upon the slab nearly in its normal position, with a portion of the left maxillipede by its side, suggesting the probability of the head being also concealed in the matrix beneath. The operculum, or thoracic plate (*o*), with its central lobe (*c*), is seen *in situ* overlying the first and second body-segments. The trunk is nearly entire, and only slightly compressed along the right side. The telson (*t*) is detached from the last segment. These three specimens are destitute of heads and appendages (save the two median appendages mentioned), but they serve well to illustrate the general form of the body at three different periods of growth. The first and largest would, if restored, represent an individual about five feet in length; the second one about three feet six inches; and the third about two feet. They are all from the "Arbroath paving-stone." The fourth, and smallest, but by far the most perfect specimen hitherto met with, was obtained by Mr. Powrie from the indurated shale overlying the "Arbroath paving-stone." From this shale, which is very finely laminated, and breaks up throughout into cuboidal fragments, Mr. Powrie has also obtained many new and interesting species of Fishes.[2]

The specimen is figured of the natural size at Plate II, fig. 1, and, although the dorsal surface is exposed, the whole animal has been so flattened out and compressed that some of the organs of the mouth are seen, as faint impressions, through the integument of the head, whilst the remainder are displaced so as to be exposed upon the surface of the shale immediately in front of it.

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[1] It was probably considerably broader, as one side is very much plicated along the margin for almost the entire length of the body.

[2] See Mr. Powrie's valuable paper upon the geology of this district, with descriptions of the Fish Remains, &c., discovered by the author, 'Quart. Journ. Geol. Soc.,' 1861, vol. xvii, p. 534.

One of the antennæ (*c*) is well seen, with its large denticulated chela, but only the three distal articulations can be discerned. Three gnathites, or jaws, are seen upon the right side of the head, and five on the left; there is little doubt that the two gnathites, marked 1, 1, in the figure, although now on opposite sides, both belonged to the right side; also one of the detached seven or eight jointed palpi of the gnathites (probably the third from the front) on the left side belonged to the right. Figures 1, of the right series, and 2 and 3 of the left side, show the gnathites with their palpi attached. The great swimming-foot, or maxillipede (5), on the right side, has been twisted round the wrong way, and lies with its inner margin turned outwards. The gnathite marked 4, on the right side, probably belonged to it. That on the left side is but little displaced, and exhibits the gnathite (5) with its broad rowing appendage still attached.

The swimming-feet of this specimen exhibit at *i*, *i*, a small, somewhat triangular plate, united to the border of the penultimate joint, and overlapping the oval terminal palette. This has not been observed before in *Pterygotus anglicus*, but I had already detected it in *P. perornatus*, *P. bilobus*, *Slimonia acuminata*, and *Eurypterus lanceolatus;* and it is figured by Prof. James Hall in his history of the American species of *Eurypterus*.[1]

The impress of the large heart-shaped metastoma, or post-oral plate (*m*), can clearly be discerned in the centre of the head, and the large oval marginal eyes (*o*, *o*) are also to be observed on the anterior border. Even the outline of the thoracic plate, or operculum, is seen beneath the first and second segments of the body.

The immature condition of this specimen is indicated, not only by its comparatively small size (eleven inches in length), but also by the extreme thinness of its integument, the whole body being folded or crumpled obliquely across the fourth, fifth, and sixth somites, and also across the telson or terminal joint. The indications of a central ridge upon the three last abdominal segments is but very slight as compared with the same segments in more adult individuals. The telson is much narrower in proportion to its length, as compared with the large example figured on Plate VI, whilst its extremely thin but prominent central ridge is folded down towards the right side of the median line, leaving only a faint mark upon its surface.

On Plate I, fig. 4, is represented a minute but almost perfect specimen, named *Pterygotus minor* (see Geol. Mag., vol. i, p. 199, pl. x, fig. 2), from the same indurated shale as the above example, and in a precisely similar state of preservation. The eyes in *P. minor* are more within the margin of the head than in the larger specimen (Plate II, fig. 1), but we should not place implicit reliance upon this character, as, no doubt, in the earliest stage the eyes closely approximated.

Detached portions and appendages of Pterygotus anglicus.—Although for the purpose of obtaining a correct idea of the general form of the body and the position of the appendages, entire specimens, such as the foregoing, are invaluable, we must not, therefore, omit to study carefully the far more numerous detached portions which have been met with, and the separate parts of appendages, as they not unfrequently offer details less clearly seen in the more perfect remains.

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[1] 'Nat. Hist. New York,' "Palæontology," vol. iii, 1859, pp. 397 and 400

We have only to turn over the first seven plates, and especially to note the beautiful series of appendages figured in Plate VII,[1] to be convinced of their great value, not only in enabling us to complete our knowledge of the anatomy of these very ancient Crustacea, but also accurately to ascertain their proportions.

The Carapace.—At the period of the publication of Messrs. Huxley and Salter's Monograph the only examples of the carapace of this genus were in the collection of Lady Kinnaird.[2] One of these curious flattened plates is figured at plate iii, fig. 1, of that work, which led to the conclusion that the head-shield was trapezoidal in form when perfect (op. cit., p. 11); but the tolerably perfect detached head figured on Plate I, fig. 2, shows a decidedly semicircular front, as is also well seen in the head of the nearly entire but smaller specimen (Plate II, fig. 1), in which the posterior angles are also considerably rounded off where the carapace is united to the thoracic somites.

The organs of the Head.—In speaking of the paired appendages of the cephalon, we shall observe the same order as is given for the restored figures of ***Pterygotus anglicus***, in the explanation of figs. 1, and 2, Plate VIII.

The Eyes.—Both the detached head on Plate I, fig. 2, and that on Plate II, fig. 1, exhibit the large convex marginal eyes upon the antero-lateral border of the carapace; but I am unable, in these or in any of the other specimens which I have examined, to detect the facetted surface of the cornea. Mr. Salter, however, has satisfactorily made them out in the specimen from Lady Kinnaird's cabinet, and says (Mon. cit., p. 68.)—"The lenses are rather large, about eight rows in one tenth of an inch, and in this specimen are rhomboidal rather than hexagonal, at least in arrangement; this may be due to pressure only." (See 'Survey Mon.,' pl. iii, fig. 1, 1*a*, and 1*b*.) Prof. Huxley observes (op cit., p. 20)—"Notwithstanding the peculiar character of the markings upon the corneal surfaces of these eyes, I wait for better evidence than I have hitherto met with, before deciding that they were really compound, and that these markings indicate corneal facets."

No ornamentation can be detected on the head-shield of the smaller specimen (Plate II, fig. 1), but the surface of the larger detached carapace (Plate I, fig. 2), when magnified, presents a finely punctated appearance, as represented in Plate I, fig. 2*a*, but there is no appearance of any scale-like markings upon it, as upon the appendages and somites.

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[1] Copied (with the exception of fig. 4) from plates vi and vii of Messrs. Huxley and Salter's Monograph on the *Eurypterida* (1859), from Mr. C. R. Bone's very excellent figures.

[2] Although these and other specimens are spoken of in the 'Survey Monograph' as "from the collection of Lord Kinnaird," I am informed by my friend Mr. Powrie that it is her ladyship who is especially devoted to palæontology; and I therefore beg leave to associate her name with these interesting specimens in the collection of which she has taken so much interest.

The chelate Antennæ.—The very fine examples of these organs drawn on Plate VII, figs. 1—3, from specimens in the museum of Lady Kinnaird, Rossie Priory, Perthshire, and the Watt Institution, Dundee, still remain unrivalled. Three joints at least may be observed in this member. "The first is an elongated subcylindrical stem, flattened by pressure," in fig. 2, but retaining its normal rounded form in fig. 4; "the next, short, enlarged, and swollen, is produced into a long slender process, pointed and incurved at its extremity, and beset with very strong and numerous unequal striated teeth. The third joint is articulated with the enlarged basal joint of the second, so that its similarly incurved extremity is opposable, like a thumb, to the latter. It possesses teeth of a similar structure to those in the other ramus of the chela, and opposed to them as the canine teeth in the upper jaw of a mammal are opposed to those in the lower, passing, that is, behind the others, or on their proximal side."[1]

From a careful comparison of these organs with the less rare and often better preserved remains of *Pterygotus bilobus* and *P. perornatus*, they have been placed in front of the mouth (Plate VIII, figs. 1, and 2, 2, 2). We have no evidence that the coxal, or basal joints of these chelate appendages were converted into gnathites; but the corresponding simple pair of organs in *Slimonia* and *Eurypterus* (and probably also in *Stylonurus*), are made to fulfil the office of jaws. It was probably this fact, which led Prof. Agassiz[2] to conclude that the antennary system was entirely absent in the *Eurypterida*, but the antennæ in *Limulus* (see Plate IX, fig. 1, 3, and 1*a*) also act as gnathites; and if we accept Prof. Huxley's view, that these chelate organs in *Pterygotus* represent the antennæ, and assume the antennules to be aborted, the remaining mouth-organs will be found to correspond exactly in number, with *Limulus*.

The Endognaths, or Mandibles and Maxillæ.[3]—The three pairs of organs which follow after the antennæ are apparently almost identical in form.

At Plate VII, figs. 5, 6, 7 and 8, represent the best detached examples of these appendages that have as yet been discovered, whilst at Plate II, fig. 1, we see several nearly entire endognaths, but too small to show more than the general outline.

The basal joint is large and flat, and produced almost to a point at one extremity (figs. 5*p* and 6*p*), where it was evidently attached to the head, and truncated obliquely to its long axis at the other. The truncated margin is slightly curved, and is beset with strong curved and pointed teeth, which are longer at one end of the series (*a*), than at the other (*b*), and are so constricted at their bases as to appear to be articulated with the basal joint (*a*, *b*, figs. 5, 6 and 7). On the outer part, immediately above the pointed extremity (*p*), is inserted the basal joint of the long palpiform appendage. The first two (?) joints of the palpus are much shorter, and thicker than the succeeding ones, which were subcylindrical and nearly equal in length for the next succeeding three articulations, ending with two short joints, the terminal one being pointed and slightly curved. The characteristic sculpture is visible upon a portion of the surface of the basal joint of these appendages (see figs. 5—7).

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[1] Prof. T. H. Huxley, Surv. Mon., p. 14.

[2] Hall's 'Palæontology of New York,' 1859 (see ante, p. 18, ¶ 47).

[3] This description is taken *in part* from Prof. Huxley's Survey Mon., p. 15 (*b*).

The Ectognaths, or Maxillipedes.—These are by far the most complete and well-preserved of any of the appendages met with, and are represented by two basal joints, or *coxognathites* (Plate I, fig. 3, and Plate IV); by a very large penultimate joint, or *prognathite* (Plate V); by an almost entire maxillipede, or *ectognath* (Plate VII, figs. 9, 10), all of the natural size; and lastly, by part of another example (Plate VII, fig. 11), three fourths the natural size.

These mouth-appendages, which occupy the most posterior position in the series (see Plate II, figs. 1, 5, and Plate VIII, figs. 1, 6), and probably correspond to the first pair of maxillipedes in the *Decapoda*, and the sixth pair of appendages in *Limulus* (see Plate IX, figs. 1, 7), are evidently the most important and powerful manducating organs, as well as being also the principal locomotory appendages.

Prof. Huxley (op. cit., p. 16) thus describes an ectognath:—"It consists of an exceedingly large and expanded, quadrate, basal joint, produced at one angle into a broad curved process, which is obliquely truncated at its extremity. The truncated edge is nearly straight, and is serrated, broad notches separating a number of strong, flattened, pointed denticles, which are continuous with the substance of the joint, and not articulated with it (see Plates I, fig. 3 *m*, and IV, *m*.)

"The denticles or serrations form a single series, and diminish in size from one end of the series to the other. The smallest is succeeded by the rounded corner in which the truncated edge and the concave margin of the serrated process meet.

"The surface of the joint and of its process is covered with the squamiform ornamentation, and presents in the middle of the margin, opposite to the serrated process a deep notch (Plates I, fig. 3 *s*, and IV, *s*), which receives the first joint of the long palpiform remainder of the appendage. This portion consists of six articulations, the penultimate of which (Plate VII, fig. 10, *g*, and fig. 11, *g*) is much larger than any of the others, is elongated, broad, flattened, and widely emarginate at its distal extremity, where it articulates with an oval palette-like plate, with serrated edges.

"From the form of the articulating edges of the joints of the palpiform part of this appendage, I am inclined to think that, as in the chela of the lobster, the plane of motion of each joint formed a considerable angle with that of its predecessor and successor, the result of which would be a sort of feathering, or screw-propeller motion, of the ultimate and penultimate joints during flexion of the limb."[1]

In the recent state these appendages undoubtedly required for their effectual action the presence of large and powerful muscles, and we obtain evidence, in the thickness of the joints themselves, of the spaces which they formerly occupied. This is well seen in the coxognathite, figured on Plate I, fig. 3, which lifts out of its stony matrix, showing the opposite side (destitute of ornamentation), the stoutest part being three eighths of an inch in thickness. In aged specimens the size of the paddles must have been very great, judging from the single articulus which we figure at Plate V. This large penultimate joint (*prognathite*) measures seven and a half inches in length by four and a half inches in breadth, and has a dorsal ridge two inches in height, which, no doubt, afforded a fulcrum for the attachment of very powerful muscles.

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[1] Such an arrangement, in fact, as is to be seen in the limbs of Swimming-crabs (see Plate IX, fig. 8).

The Metastoma or post-oral plate.—This median appendage is considered by Prof. Huxley to be formed by a fold of the integument, and not to represent a distinct somite. It is symmetrical in form, and is seen *in situ* on Plate II, fig. 1 *m*, and Plate VIII, fig. 1 *m*. It no doubt represents the *labium*, and served more effectually to enclose the posterior part of the buccal orifice, being found exterior to the toothed edges of the ectognaths or maxillipedes.

The form of this appendage is heart-shaped in Pterygotus, and was, no doubt, attached only by its narrow end to the posterior border of the head upon the under side (Plate III, fig. 1 *a*), with its broader and bilobed end directed forwards (Plate III, fig. 1 *p*). The surface is covered with the same characteristic scale-like markings as those seen upon the body-segments, and, like the other plicæ, they have their convexities directed backwards towards the narrow posterior border (*a*). The large post-oral plate which we figure on Plate III measures five and a half inches in length and four inches in breadth.

The Thoracic plate, or Operculum.—This plate was one of the mutilated portions of *Pterygotus anglicus* first discovered and figured by Prof. Agassiz in 1844,[1] which (together with other fragments) has been reproduced in Lyell's 'Elements of Geology.'[2] A fine series of the detached plates are figured in the 'Survey Monograph,' plate iii, figs. 2—7, but no specimen had at that time been discovered *in situ*.

Mr. Page first drew attention to the occurrence of this plate in its natural position in *Slimonia*,[3] but considered it to be the "anal plate."

Dr. J. Nieszkowski[4] pointed out the true position of this plate in the Russian species of *Eurypterus*, in 1858; and in 1862, Mr. Salter[5] expressed his concurrence in the views of Dr. Nieszkowski and Professor Hall,[1] and corroborates their statements, on the evidence of specimens in the collection of Mr. Robert Slimon, of Lesmahagow, Lanarkshire.[2] In a paper published in 1863 I described one of these thoracic plates, which had been found by Mr. Slimon, attached to a very perfect specimen of *Slimonia acuminata*.[3] If any uncertainty still existed as to the position of this organ, its discovery in place, in *Eurypterus*, *Slimonia*, and in two species *Pterygotus*, ought to preclude all further doubt.

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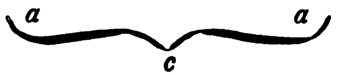
[1] See Bibliography, ante, p. 22, ¶ 20.

[2] I observe the reference to these figures in the 6th edition of Sir Charles Lyell's 'Elements of Geology' (1865), p. 523, fig. 590, has by some oversight remained unaltered. The portion of a Thoracic plate (I) is referred to the "back of the head" (as suggested by Prof. M'Coy), and the fragments 3 and 4 (the first being part of a maxillipede, or ectognath, and the 2nd the chela of an antenna) still remain united. But a reference to the explanation of fig. 591, p. 524, gives the correct position of these several appendages. The central ridge, however, seen (in fig. 591) upon the penultimate joint (12) and the telson (13), ought not to have been visible, as the figure represents the *ventral aspect* of the animal.

[3] See Bib., p. 27, ¶ 46. [4] Ibid., p. 26, ¶ 43. [5] Ibid., p. 28, ¶ 51.

This plate is well seen, in its normal position, *i.e.* upon the ventral surface of the fossil behind the head, and overlying the two first free thoracic somites, in the figure of the entire body of *Pterygotus*, Plate I, fig. 1 *c;* and it can also be discerned on the young specimen figured upon Pl. II, fig. 1. We have represented it in the restored figure of this species, at Pl. VIII, fig. 1, *op.*

Portions of five of these opercular plates are figured in the Survey Monograph on *Pterygotus* (Pl. iii, figs. 2, 3, 4, 5, and 7), but it was at that time assigned to the head, as the conjoined epistoma and labrum, being, as before stated, only known from detached and imperfect specimens. This plate (which is closely sculptured with the same characteristic scale-like markings as those seen upon the body segments, especially at its anterior or attached border) is divisible into three well-marked regions: 1st, a narrow, central lobe, rounded at its distal free end, and hastate at its proximal end, which is directed forwards, and nearly touches the posterior margin of the labium (Plate I, fig. 1 *c*). Secondly, two wide lateral alæ, which are united to the sides of the narrow median lobe, and rounded off at their lateral and posterior free borders, but are nearly parallel along the anterior margin, by which it was, no doubt, attached to the head. The free extremity of the median appendage projects beyond the lateral alæ, forming together a border very like a bracket, thus:



a a being the lateral alæ, and *c* the projecting median lobe.

In some specimens a faint indication of a suture is to be discerned on the centre of this median appendage, and in *Eurypterus lanceolatus*[4] the division is very clearly marked.

One cannot fail to notice the great resemblance which exists between the thoracic plate, or operculum, of these palæozoic crustaceans and the corresponding plate in the recent *Limulus* (Plate IX, fig. 1, 8, and fig. 1 c).

Its position is the same in each—being attached to the posterior part of the head-shield. In *Limulus*, the median part is double, being composed of a pair of jointed appendages (see Pl. IX, fig. 1 c, *d*, *d*), but in young *Limulus* these are anchylosed together, as is the case in *Eurypterus* and *Pterygotus*.[5] Professor Hall evidently considers

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[1] See Bib., p. 28, ¶ 47.

[2] Ibid., p. 25, ¶ 35.

[3] Ibid., p. 29, ¶ 53.

[4] Geol. Mag., vol. i, pl. v, fig. 8.

[5] See the observations of Prof. Agassiz, in Hall's Palæontology of New York, Part vi, vol. iii, p. 395.

the lateral alæ of this plate in *Eurypterus* to be composed of the sternal pieces of the first and second thoracic segments welded together.[1] But the thoracic plate, or operculum, in the *Eurypterida*, is formed upon precisely the same plan as in the *Xiphosura*, namely, by the coalescence of the last pair of appendages of the cephalic buckler, and it only lies folded close to the under side of the anterior somites. The lateral expansions on each side the median appendage are united to it, and really form a part of this pair of modified legs, which, in *Limulus*, bear upon their inner and upper surface a pair of ovaries or reproductive organs.

In *Limulus* the operculum (Pl. IX, fig. 1, 8, and fig. 1 c) is succeeded by five other membranaceous anchylosed pairs of appendages, alike to it in form, but thinner, and bearing branchiæ upon their inner and upper surface. It is reasonable to assume that the *Eurypterida* also possessed these organs, and that, in all probability, the opercular or thoracic plate carried the former (*i. e.* the sexual organs), whilst one or more thinner plates, destitute of scale-like markings upon their surfaces, were concealed beneath it, as the branchial plates lie hidden beneath the operculum in *Limulus*, but which are extended in the act of swimming.

The thoracic plate, or operculum, may then be regarded, not as a median appendage, like the metastoma, or post-oral plate, but as a pair of coalesced appendages, making seven pairs of organs to the head. (See Plate VIII, fig. 1.)

The body of Pterygotus is seen to be composed of twelve somites or segments, and a telson, or terminal joint; the surface of both the upper and the under sides is covered with scale-markings, which are more numerous along the anterior half of each segment than near the posterior border, which is usually plain. The segments gradually increase in width from the head backwards to the fifth segment, when they as gradually become narrower to the eighth; the breadth then decreases more rapidly, and the length of the segments is considerably increased, until, in the specimen on Pl. II, fig. 1, the twelfth segment is as long as it is wide. The form of the margins of the anterior segments is extremely parallel, as well seen in the remarkably fine detached segment figured on Plate II, fig. 2, the original of which measures eighteen inches in breadth.

This was probably about the third segment from the head, and is more than four

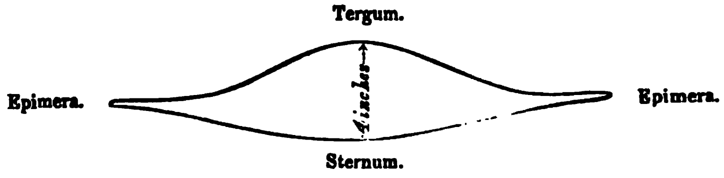

FIG. 5. Section of anterior part of the body in *Pterygotus anglicus*.

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[1] Op. cit., 398.

times as wide as it is long. It is strongly arched in the centre, and the body at this point was not less than three to four inches in thickness. When seen in section it presents somewhat the form represented in the accompanying woodcut. (Fig. 5.)

Two apodemata are directed forwards on either side from the epimera of the anterior border of this somite (Plate II, fig. 2, *a*, *a*), by which it was evidently united to the preceding segment. The other body-rings were, in all probability, joined together by similar internal processes from the shelly-envelope, affording solid points of attachment for the powerful muscles which doubtless formed—as in the Macrouran Decapod—almost the entire bulk of the huge apodal trunk in *Pterygotus* and its allies.

As we recede from the head, we find that, at about the seventh, or first abdominal somite, the posterior edge becomes more curved, and there is a slight tendency along the lateral borders to develop into falcate epimeral extensions. The last three segments become slightly keeled along the centre of the tergum, and the border of all the posterior segments is somewhat bluntly serrated.

The very perfect ante-penultimate body-segment which we have figured on Pl. III, fig. 2, having both its upper and under surfaces preserved, shows the exact thickness of this somite to have been three inches: an end view gives a section as under. (Fig. 6.)

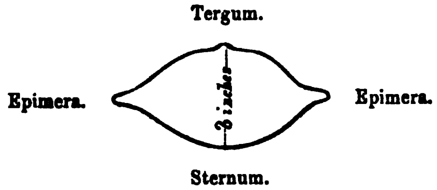

FIG. 6. Section of posterior part of the body of *Pterygotus anglicus.*

Mr. Salter, in his description of *Pterygotus anglicus*,[1] gives a woodcut of a segment extremely like the one figured on Pl. III, fig. 2, showing both the upper and under side. The specimen is stated to be from Leysmill, Forfarshire, and may possibly be the same example. He calls attention[2] to the variation which is noticeable in the form of these posterior segments, and suggests that the difference may be due to sex, and not to any specific distinction.

The telson, or terminal segment, is obtusely hastate, and strongly keeled upon its dorsal surface. It varies apparently with the age of the individual (see Pl. I, fig. 1 *t*, Pl. II, fig. 1, and Pl. VI). There are no scale-markings visible on this appendage,

[1] 'Mem. Geol. Surv.,' Mon. I, p. 71, fig. 10.

[2] Op. cit., p. 72.

except near its proximal or attached end, but it is ornamented with rough, blunt squamæ and serrations along the lateral margins.

The telson figured on Pl. VI is the largest known, and measures nine inches in length by seven inches in breadth.

In describing the divisions of the body in *Pterygotus anglicus,* we have spoken of the head and the body, avoiding the terms "thoracic" and "abdominal somites" as much as possible. On reference to the restored figure at Plate VIII, fig. 1, it will be seen that there is evidence, according to the paired appendages (see *antè,* p. 6), of 7 somites having coalesced to form the cephalic division.

Assuming that all the segments united to form the head are represented by pairs of appendages, we have then a true Cephalon; the 7 succeeding free somites are thoracic, the abdomen being represented by 5 somites[1] and a telson, or terminal joint. But assuming the antennules to be wanting (see *antè,* p. 37), we must conclude the head to represent 8 coalesced segments, that is to say, 7 cephalic and 1 thoracic, the latter bearing the "operculum," or "thoracic plate" (Pl. VII. fig. 1 *op*).

In this case only the first six anterior somites will be counted as thoracic, the posterior six will be reckoned as abdominal, and the 'telson' will make up the 21 segments.

The likeness which *Pterygotus* offers to *Limulus* is very much strengthened by this latter view. As we proceed to the illustration of the other genera belonging to this order, we shall be still more strongly impressed with the many points of close resemblance which they will be found to exhibit.

The *Merostomata* seem, in fact, to present us, in these early times, with a parallel group of *Crustacea* to that embraced in the order *Decapoda* at the present day; the *Macroura* being represented by *Pterygotus* and its allies, the *Brachyura* by *Limulus,* &c., and the intermediate forms, like *Hemiaspis,* &c., being comparable to the *Anomoura.*

We could scarcely, in the whole Zoological Kingdom, point to a stronger illustration of the persistence of type than is to be observed in these Palæozoic forms.

From our present knowledge of the almost perfect remains of *Pterygotus anglicus,* and on the evidence of the numerous detached portions of this extinct genus, we are justified in concluding that it attained a length of six feet, and a breadth of nearly two feet at the widest part of its body.

From its large eyes, its powerful natatory appendages, and from the general form of its body, we may also infer that it was a very active animal. Its great prehensile antennæ and rows of serrated jaws, further indicate its predacious habits, whilst from its size it must have been the shark of the Devonian seas.

"No existing Crustacean," observes Prof. Huxley, "has so massive a body as *Pterygotus,*" . . . . "but mass in an active animal involves large muscles, and these require solid *points d'appui.* Hence, we may conclude that the integument of the *Pterygotus,* thin and fragile as are its remains, possessed a great amount of firmness in the recent state."[1] In the living *Limulus,* the shell is equally thin to that of the fossil *Pterygotus,* but this leathery integument nevertheless affords attachment to very powerful muscles.

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[1] See Dr. Milne-Edwards' observations on arrested development, *antè,* p. 6.

Distribution.—This species is peculiar to the LOWER OLD RED SANDSTONE, and has been obtained at Balruddery, Perthshire; at Leysmill near Arbroath, at the quarries of the Turin Hills, near Reswallie, at Tealing and Carmyllie, and other places in Forfarshire.

The specimens figured are from the collections of Lady Kinnaird, James Powrie, Esq., the British Museum, and the Watt Institution, Dundee.

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[1] 'Mem. Geol. Surv.,' Mon. I, p. 36.

A MONOGRAPH
OF THE
BRITISH FOSSIL CRUSTACEA
OF THE
ORDER MEROSTOMATA.

PART II.

INTRODUCTION.

GEOLOGY OF LESMAHAGO, LANARKSHIRE.

As this and the succeeding part of the Monograph will be mainly occupied with the description of species of *Pterygoti* obtained from one locality, namely, the parish of Lesmahago, in Lanarkshire, I have thought it not out of place here to prefix a short description of the district by Sir Roderick I. Murchison, Bart., who, with Prof. Ramsay, visited Lesmahago in 1855, accompanied by Mr. Robert Slimon, for the purpose of studying the geology of this locality.

This account, although written some years since, is in the main confirmed by an examination subsequently made by Mr. A. Geikie, F.R.S. (now Director of the Geological Survey of Scotland), who, in an admirable paper[1] (published in the 'Quart. Journ. Geol. Soc., Lond.,' 1860, vol. xvi, p. 312), traces out the connection of these extreme northern Silurian deposits with those of the Pentland Hills in Edinburghshire.[2] (See also 'Siluria,' 4th edition, 1867, pp. 159—162.)

I think this description the more necessary inasmuch as the name of the district has now become so familiar to all collectors of palæozoic fossils, by reason of the vast number of specimens (chiefly of *Crustacea*) obtained by Mr. Robert Slimon and his sons, and now distributed through the museums and private collections, not only of this country, but also of Europe and America.

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[1] One of Mr. Geikie's sections illustrates this Introduction. See page 51.

[2] The officers of the Geological Survey and subsequently Mr. G. C. Haswell, of Edinburgh, have discovered remains of *Pterygotus* and *Slimonia* in the Upper Silurian rocks of the Pentland Hills.

ON THE DISCOVERY, BY MR. ROBERT SLIMON, OF FOSSILS IN THE UPPERMOST SILURIAN ROCKS, NEAR LESMAHAGO, IN SCOTLAND, WITH OBSERVATIONS ON THE RELATIONS OF THE PALÆOZOIC STRATA IN THAT PART OF LANARKSHIRE. BY SIR RODERICK IMPEY MURCHISON, D.C.L., F.R.S., V.P.G.S., AND DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY.

(Reprinted, by permission, from the 'Quarterly Journal of the Geological Society of London' for 1856, vol. xii, pp. 15—19.)

"*Introduction.*—At the last meeting of the British Association [in 1855], Mr. Robert Slimon brought to Glasgow two remarkable collections of fossils from the extensive parish of Lesmahago, in which he practises as a surgeon. One of these collections was derived from the bands of Carboniferous Limestone, which there alternate with Coal, and are characterised by a great abundance of fine specimens of *Producti*, *Encrinites*, Corals, and other remains peculiar to deposits of that age. The other consisted of specimens of Crustaceans in dark-coloured schist or flag, and to two or three specimens of which my attention, as President of the Geological Section, was fortunately called by Mr. David Page. The magnificent collection of Mr. R. Slimon had, in fact, remained almost unobserved, in a hall which few geologists visited.

"The moment I cast my eye over these remarkable Crustaceans, which much resembled *Pterygoti*, and saw the matrix in which they were imbedded, it occurred to me that they probably pertained to the Uppermost Silurian zone. It became, therefore, necessary to visit the locality in question, chiefly for the purpose of ascertaining the physical relations of the dark schist with large Crustaceans to the Old Red Sandstone. For, as I was aware that the genus *Pterygotus* had been found as low in the Silurian rocks as the Upper Caradoc band, it might prove that there was the same great hiatus near Lesmahago as had up to this time been supposed to prevail all over Scotland, and that no representative of the Uppermost Silurian existed. On the other hand, the band in question might prove to be that which I shall endeavour to show it is, viz. the true representative of the highest Silurian zone, as developed in Herefordshire, Shropshire, and Westmoreland in England, in Russia on the Continent of Europe, and also in North America.

"Having requested Prof. Ramsay to accompany me, we visited Lesmahago together, and there found, to our gratification, that the worthy and modest Mr. Slimon had not only a much richer collection of the fossils in question than he brought to Glasgow, but had also an accurate acquaintance with many of the prominent and detailed features of the tract. Guided by him to the best natural sections, and particularly to the spot on 'Logan Water,' hitherto famous only in Scottish song, where he had found the Crustacean fossils, we afterwards endeavoured to obtain a general notion of the relations of all the rock-masses of the district." * * * * *

"*General Relations of the Rocks of the Lesmahago District.*—In a former communication I invited attention to the general direction of the great masses of the Silurian rocks of the South of Scotland, which have been described by various authors under that name, since the discovery in them of many well-known Silurian fossils.[1] I then suggested that, judging from some of those organic remains, as found in the environs of Girvan, there were indications, in that parallel, of an ascending order from the Lower Silurian rocks (which unquestionably form the great mass of the South-Scottish Greywacke) to the Upper Silurians. At the same time it was noticed that the strike of the Girvan strata would carry them nearly to the Silurian rocks of the Pentland Hills, south of Edinburgh, which have the same general direction, *i. e.* nearly from north-east to south-west. Now, if a line be drawn from the rocks north of Girvan to the northern face of the Pentland Hills, it is seen to pass over an intervening tract, throughout which basins of Carboniferous rocks, surrounded by girdles of Old Red Sandstone and diversified by a great abundance of igneous rocks (porphyry, greenstone, &c.), are represented in all the published geological maps. The discovery made by Mr. Slimon of fossils which prove to be of Upper Silurian age, over a considerable area in the extensive parish of Lesmahago (for this Scottish parish has a length of twenty-five miles), has advanced, therefore, the northern frontier of the Silurian or slaty rocks; some of the localities in question being not less than twenty miles to the north-west of their previously defined boundary. The extent to which the Lesmahago Silurians may be hereafter shown to be connected upon the surface with those of the tracts around the Lead Hills, and other parts of Ayrshire and Dumfriesshire, on the south and south-east, must be a work of future labour. That work will demonstrate whether these Lesmahago rocks constitute an advanced Silurian promontory or headland, or whether, as is most probable, they form an outlier of that age.

"The large parish of Lesmahago is pre-eminently distinguished in its western part by dome-shaped hills, which rise to the south-west of the River Clyde, and on the left bank of that river, where it forms the well-known beautiful Falls of Bonnington and Stonebyres, near the town of Lanark. The rock over which the Clyde cascades is the Old Red Sandstone, which formation, extending to the west and south-west to the village and parish of Lesmahago, is overlain on the north and south by Carboniferous Limestones and Coal, whilst on the south-west it is underlain by the dark and schistose rocks to which attention is now specially invited.

"*Upper Silurian Rocks.*—The relations of these dark grey, schistose strata of clay-slate to the Old Red Sandstone are seen on the banks of the Nethan River, and also on those of other tributaries of the Clyde, particularly the Logan Water, on each of which rivers Mr. Slimon has marked the junction between the grey Silurian and the Old Red rocks. The Silurian beds rise up into several hills of considerable altitude, one of which (Nutberry, 1715 feet above the sea) we ascended. Judging from the outline of the country, and the extensive range of similar high moorlands, I am disposed to think that these rocks may be found to spread north and westward over the hills of Dunside and Middlefield, 1300 to 1500 feet high, and may even range to Cairn Table on the south, the summit of which, according to the Trigonometrical Surveyors, is 1944 feet above the sea. Advancing eastwards from the range of hills on the flank of Nutberry, in one part of which Mr. Slimon discovered an Orthoceratite, and descending the Logan Water to about a mile below the farmhouse of Dunside, you reach the uppermost band of the grey strata in which were discovered those remarkable Crustaceans which have been above referred to.

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[1] 'Quart. Journ. Geol. Soc.,' 1851, vol. vii, p. 137.

"The lowest portions of the Silurian rocks which fell under the inspection of Prof. Ramsay and myself are those which are traversed by the Nethan River as it flows from Priest Hill and Nutberry Hill to Cumberland. Several dislocations and convolutions which are seen on that line among Silurian strata, as well as in the contiguous Old Red, are well explained by the frequent protrusion of porphyry (usually a red quartziferous porphyry). On the whole, however, it was manifest to both Prof. Ramsay and myself that in receding from the Old Red boundary, and in ascending to the higher hills by the course of the Nethan, we made a gathering, descending section, because the strata, succeeding to each other with a prevalent dip to the north-east or east-north-east, consisted successively of differently constituted materials. Thus, whilst the uppermost strata were dark grey and schistose, other layers of lighter colours were more siliceous and formed stonebands. These are followed by other courses of shale and schists, in which are nodular concretions, occasionally calcareous, in which we looked in vain to find a few fossils which could have led us to suppose them (what they might very well prove to be from mineral aspect) the representatives of the Wenlock formation. It is from one of these strata that Mr. Slimon procured the Orthoceratite above alluded to, but which is too imperfect to be specifically determined. With some undulations and several breaks, particularly in the proximity of the intrusive porphyry, all these Silurian strata are inclined towards the east-north-east and north-east, and at angles varying from 12° and 15° to verticality where they roll over in flexures.

"The inferior beds exposed in the section of the Nethan are here and there mineralized, and specially so where trap-rocks, chiefly greenstone, have penetrated the strata, veins of lead-ore and much sulphate of barytes being there apparent on the surface.

"The section, however, which best exhibits the relations of the Silurian rocks to the Old Red Sandstone is seen on the banks of Logan Water, between the farms of Dunside and Ach Robert. The last of the decidedly dark grey and schistose beds observable in descending from the flanks of the Silurian hills (Nutberry, &c.), are those in which all the fossils described by Mr. Salter[1] were found by Mr. Slimon. These dark fossiliferous rocks, the clay-slate of mineralogists, are immediately overlain by and pass up into Red Sandstone, in which there are several alternations of more or less greyish or greenish-grey bands, the whole, like the beds in the Nethan, dipping to the east-north-east or north-east.

" *Old Red Sandstone.*—In the traverse along the Logan Water I did not observe any unconformity between the grey beds with Crustaceans and other fossils and the overlying red sandstones, the lowest courses of which are marked upon Mr. Slimon's unpublished map as 'Red Silurians.' For my own part, however, I would rather consider these red strata as constituting the base of the Old Red Sandstone, because they graduate up into, and alternate with, the pebbly conglomerates which are largely developed near Ach Robert and Waterside.

" Some of the porphyries which are associated with the red rock in this part of the series seemed to be interstratified and of age contemporaneous with the sandstones with which they dip symmetrically, and like which they are jointed and exhibit the way-boards of sedimentary deposits. In mineral characters and in their interstratification with red sediments, these rocks, though of much older date, present much the aspect of some of the porphyries of the Rothe-todte-liegende of the Permian age in Germany.

"The conglomerates of the Old Red of this tract differ strikingly from those of the same age in the North Highlands, where the so-called lower conglomerate is usually a very coarse breccia, the huge fragments of which are more or less angular, whilst here they are all worn and rounded pebbles, the largest of which scarcely ever reaches a foot in its greatest diameter.

" Most of the pebbles consist of grey and pink quartz-rock, but these are mixed with other varieties of crystalline and some igneous rocks. This conglomerate zone, which is fairly interstratified in red sandstone, and ranges from north to south (as laid down on Mr. Slimon's map), is much nearer to the dark grey Silurian on the Nethan River than it is to the same rock on the Logan Water; whilst on the Kype Water the two rocks are still further removed from each other. Time and detailed examination will determine whether this deviation of outline be due to breaks and unconformable arrangements, or simply to changes in the degree of inclination of the strata. By comparing the only watercourses which we examined, I am led to think that the difference of the angle of dip may sufficiently explain these diversities of superficial area, because on the Logan Water we found the inclination varying from 7° to 12° only on an average; the red beds with imbedded porphyries and conglomerates, as well as the inferior grey beds, sloping off to the north-east or east-north-east at these low angles, except where they rolled over bosses of porphyry. On the Nethan banks, on the contrary, the beds are more highly inclined.

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[1] 'Quart. Journ. Geol. Soc.,' 1856, vol. xii, p. 26.

"In ascending order the Old Red Sandstone, including all that portion of it which lies above the conglomerate, and extends by Lesmahago to the Clyde and Lanark, is usually of a lighter colour and freer quality than the subjacent beds, and occupies a very varied outline in reference to the Carboniferous Limestone and Coal-fields on either side of it, and under which it is seen to dip. On the banks of the Nethan Water, where we examined them, the junctions are much broken, and, on the whole, it would appear that the older rocks have been so convoluted as to form the southern edge of the great central Scottish Coal-field, or the complete girdle of the Douglas Coal-basin, the south-west side of which is flanked by the Old Red of the Hawkshaw Hills, and also, according to Mr. Slimon, by the Silurian rock of Bremerside Hill."*

The following short account of the relation of the *Pterygotus*-bearing shales of Lesmahago was communicated in a letter to the Author by Mr. Slimon in 1867:

"Commencing in an ascending order with what we consider to be the lowest Silurian beds of this area, we find them to be of great thickness, composed of coarse, hard, stony bands, separated by thin clayey beds of shale. The *Ceratiocaris* is the principal fossil in these lowest beds; it is very abundant, but of small size, and is associated with some shells.

"*Ceratiocaris* recurs in the higher beds, but the specimens are far larger. A fault, caused by the intrusion of a dyke of hornblende-porphyry, called the Nutberry Hill Dyke, occurs here, and is followed by a rock containing an *Orthoceras*, but ill preserved. This bed is succeeded by *Ceratiocaris*-shales splitting up into slaty laminæ, often as thin as paper. Here the *Ceratiocaris* attains its maximum development, both in size and numbers, becoming rarer in the higher beds, and disappearing altogether in the highest Silurian. In these slaty beds *Slimonia acuminata* first appears, but very small in size; as it increases in development in the higher beds, *Eurypterus lanceolatus* and *Pterygotus bilobus* (var. *a*) make their appearance, both small in size and few in numbers in the lower beds, but gradually increasing in importance in the higher; var. *a*, *inornatus*, being replaced by var. γ, *perornatus* (attaining a length of from 2 to 3 feet). *E. lanceolatus* in the lowest beds is not an inch in length, but in the highest it is of considerable size.

"*Eurypterus scorpioides* and *Stylonurus Logani* first appear in these upper slaty beds (here much disturbed by intrusive hornblende-porphyry). They are more rarely met with than other species, but appear to follow the same law as regards their gradual development and decline. I have portions from higher beds attesting their continued increase in size upwards.

"The Upper Silurian beds here described occur along the Logan Water in a distance

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* The description of the Lower Carboniferous and Igneous Rocks of the tract is here omitted.

(traversed on the dip) of about four miles; the uppermost bed containing *Lingula cornea*, *Platyschisma helicites*, *Beyrichia*, &c.

"*Dictyocaris Slimoni* also occurs in these beds, but is never obtained entire. Fragments of Trilobites (?), a few small shells, and some supposed vegetable remains, complete the list of fossils.

"In many of the beds seen in this section no fossils of any kind are found.

"These grey shaly and slaty beds dip beneath and are conformable with a series of red and grey shales of a more sandy nature than the foregoing (but unfossiliferous), extending for a mile and half; I have called them "Red Silurian," but Sir Roderick Murchison considers they should form the base of the Old Red Sandstone series. In one bed only fragments of a *Stylonurus* have been found, and one small specimen, thought to be part of a *Slimonia acuminata*, but the evidence is too fragmentary to rely on. All the strata are very much disturbed, owing to intrusions of felspar- and hornblende-porphyry, causing many of the beds to be repeated and faulted."

It is, however, to these very disturbances that we are, no doubt, indebted for the exposure of the *Pterygotus*-bearing shales of Logan Water.

The subjoined section is copied from one which accompanies Mr. Geikie's paper published in the 'Quarterly Journal of the Geological Society,' 1860, vol. xvi, pl. xviii, Section 1, and exhibits the *Pterygotus*-bearing shales as they appear in the anticlinal of the bed of the Logan Water, and the succeeding Lower Old Red Sandstone and Carboniferous deposits.

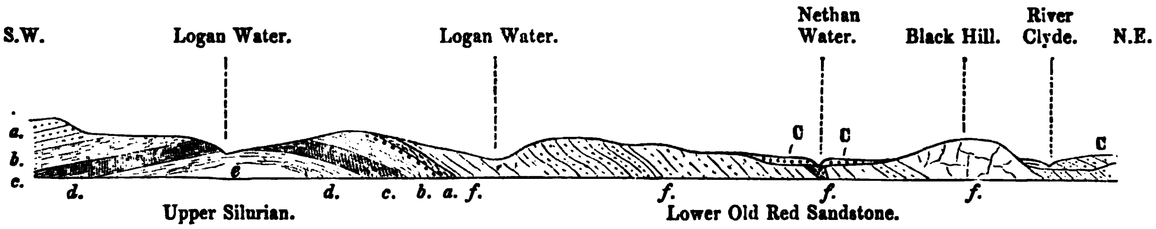

FIG. 7.—Section of the Upper Silurian and other strata near Lesmahago.
a, a. Purplish-grey Sandstones. *b, b.* Red shales, Sandstone bands, and Conglomerate. *c, c.* Olive shales.
d, d. Hard flaggy shales (*Pterygotus*). *e.* Hard shales and stone bands. *f, f, f.* Felstone.
C, C, C. Carboniferous strata (unconformable to Old Red).

MR. ARCHIBALD GEIKIE, F.R.S., the Director of the Geological Survey of Scotland, has most obligingly furnished me with the following descriptive section, in descending order, of the deposits of the Lesmahago district, taken from the joint observations of his colleague Mr. B. N. Peach and himself.

SECTION OF STRATA BELOW THE BASE OF THE OLD RED SANDSTONE IN THE DISTRICT OF LESMAHAGOW.

Basement Beds of Lower Old Red Sandstone.

a. Coarse conglomerate, chiefly of well-rounded fragments of liver-coloured quartz-rock. This is a very persistent band through the whole district.

b. Red mudstones and shales, with ripple-marks and sun-cracks. 60 to 70 feet.

c. Grey and green flaggy shales, with hard stone-partings, like portions of the Silurian series. 140 feet.

d. Red mudstones and shales, like those (*b*) below the quartzite conglomerate. 500 feet.

e. Red sandstones and fine quartz-conglomerates. 300 feet.

Upper Silurian.

f. Sandy, flaggy, green stone-bands and shales, with partings of grey and red mudstone passing conformably upwards into *e.* About 130 feet.

g. Blue, grey, and green shales, sandy mudstones and sandstone bands, becoming more sandy towards the top, and more shaly and flaggy towards the bottom. 200 feet. These are the *Trochus* beds; they contain ***Platyschisma helicites,*** three species of ***Lingula, Beyrichia,*** and some undetermined shells.

h. Hard blue and grey flaggy shales, with occasional bands of calcareous nodules. 350 feet. These are the ***Pterygotus*** beds.

i. Hard grey flagstones and bands of hard greywacke. About 500 feet.

k. Grey, blue, and olive shales, becoming more and more interbedded with hard stone-bands towards the base. About 300 feet. In some of these beds ***Beyrichia*** is very abundant; others contain ***Ceratiocaris,*** two or three species of ***Lingula,*** some shells not yet determined, ***Platyschisma helicites,*** &c.

l. Hard bands of greywacke, with shale partings. These form the lowest portion of the Silurian series visible in this district. They must be at least 2000 feet thick. Fossils are scarce, but an *Orthoceras* occurs along with plant-like markings and *Ceratiocaris.*

The total thickness of Upper Silurian strata in the neighbourhood of Lesmahago cannot be less than 3500 feet, and, as the base of the series is nowhere seen, the depth may be much more.

Although the *Pterygoti* occurring in the dark clay-slates of the Upper Silurian of Logan Water and the Nethan River are far inferior in size to the gigantic *Pt. anglicus* from the Lower Old Red Sandstone of Forfarshire and Perthshire, yet for wonderful perfection of preservation they can scarcely be rivalled, and certainly not surpassed, by similar remains from any other formation. Since the preceding description of *Pt. anglicus* was written, however, I have had the good fortune to visit the Museum of the Natural History Society at Montrose (September, 1867), and inspect the magnificent specimen of *Pterygotus anglicus* there preserved, from Lord Panmure's Quarries at Carmyllie. This unique example measures about 3 feet 6 inches in length, 13 inches across the widest segment, and is by far the most perfect remain of this species yet met with, having the head united to the complete series of body-rings, including the 'telson' or terminal segment; the body-rings themselves lifting out from the matrix and presenting both the dorsal and the ventral aspect. The thoracic plate is also seen *in situ*, the great swimming-feet (or ectognaths) attached to the head, on the centre of which last are seen the larval eye-spots (ocelli), and the great compound marginal eyes, with their facets as beautifully preserved as if it were a living Crustacean and not a remnant of a Palæozoic age. The friable condition of the fossil alone has prevented the possibility of obtaining the loan of it for delineation, but I hope to be able before the completion of this present Monograph to offer to the Society a fitting representation of this truly wonderful *Pterygotus*.

Genus 1.—PTERYGOTUS, *Agassiz.*—*Continued.*

Species 2.—PTERYGOTUS BILOBUS:—Salter. 1859.

1. var. *α*, *inornatus.*
2. var. *β*, *crassus.*
3. var. *γ*, *perornatus.*
4. var. *δ*, *acidens.*

The species about to be considered was first described by Mr. Salter, under the generic name *Himantopterus*, in the 'Quarterly Journal of the Geological Society' for 1855, vol. xii, pp. 27 and 28, where a figure is also given (reproduced in 'Siluria,' last edition, 1867, p. 162).

Of the species of *Himantopterus*, described in the paper above alluded to, two only at present call for consideration, namely, *H. bilobus* and *H. perornatus*. Mr. Salter subsequently referred these to *Pterygotus* (see 'Mem. Geol. Surv.,' Monograph 1, 1859, p. 39).

At the time of the publication of the above Monograph comparatively but few entire remains of *Pterygotus bilobus* had been obtained, whilst *Pt. perornatus* was even less perfectly known from parts of specimens.

It is probable that Mr. Slimon has obtained not fewer than several hundred specimens, more or less perfect, of *Pt. bilobus* alone, since the commencement of his labours in the shales of Lesmahago, but *Pt. perornatus* continues an extremely rare form.

If a comparison be instituted between the figures in the first plate of the Geological Survey Monograph on *Pterygotus* (published in 1859) and the six plates which accompany the present part of this Monograph, some idea may be formed of the progress which has been made in the discovery of new materials, during the past nine years, for the more complete elucidation of this remarkable genus.[1]

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[1] This progress will be still further illustrated by the genera *Slimonia*, *Eurypterus*, and *Stylonurus*, the descriptions of which will follow the present part.

VAR. 1.—I. PTERYGOTUS BILOBUS, var. *a*, *inornatus*. Pl. X, figs. 1—3.

HIMANTOPTERUS BILOBUS, *Salter*. Quart. Journ. Geol. Soc., 1856, vol. xii, p. 29, fig. 1.
—— —— 'Siluria,' 2nd edit., 1859, p. 155, foss. 21.
—— —— 'Page's Advanced Text-book,' 1856, p. 135, fig. 1.
PTERYGOTUS —— *Salter*. Mem. Geol. Surv., Mon. I, 1859, p. 39, pl. i, figs. 1—12.

Pterygotus bilobus[1] (var. *a*, *inornatus*), the original *Pt. bilobus* of Mr. Salter, is usually 5 to 6 inches in length, and somewhat less than 2 inches in its greatest breadth; the general form is elongate-oval in front, and attenuated behind (resembling the outline of a *Palæoniscus*).

In this variety the thorax is not easily distinguished from the abdomen, into which it is attenuated, the greatest width being about the fourth and fifth segment; its anterior segments are wide transversely, the posterior ones becoming less and less so, till the twelfth (19) is nearly equilateral; the telson is oblong and emarginate, and narrower than any of the somites; the antennæ are long, slender, and chelate at their extremities; the palpi (endognaths) are filiform; the swimming-feet moderately broad. These are the general characters.

Figs. 1—3, Pl. X, represent three examples of this species, the variation observable being due, to some extent, to the crumpling up, or squeezing out, which all these specimens have undergone since their original entombment.

⁂ Before proceeding further it is necessary to explain that the little numbers along the margin of the segments of each figure in the accompanying Plates correspond with the Roman numerals on the segments of the restored figures of *Pterygotus anglicus*, Pl. VIII, which appeared in the First Part of this Monograph. They are intended to remind the student that, theoretically, the head is composed of the first seven segments of the animal coalesced together to form the carapace, and that thus there are seven cephalic, seven thoracic, and five or six abdominal somites or segments (according to whether the 'telson' be reckoned as a segment or not; see Introduction, p. 5).

The head-shield is about $1\frac{1}{4}$ to $1\frac{1}{2}$ inch in breadth by an inch or $1\frac{1}{8}$ inch in length; the anterior contour is semicircular, the posterior border is straight. The compound eyes (*o*, *o*) are placed upon the latero-anterior border. They are broadly crescentic and convex, placed half below and half above the margin of the head, their extreme length being about 7 lines.[2] No lenses can be seen with the naked eye; but, when magnified, the appearance is that given in the annexed woodcut. They appear to be somewhat larger, in proportion, in this species than in the great *Pt. anglicus* (Part I, Pl. VIII). The larval eye-spots (ocelli) occupy the centre of the head-shield (see Pl. X, Fig. 3, *le*).

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[1] In the description of the species of *Pterygotus* we shall (wherever it is possible) continue to avail ourselves of Mr. Salter's diagnoses, merely altering such parts as a more complete acquaintance with the details of their structure enables us to do so with advantage.

[2] A line is always here used to signify $\frac{1}{12}$th of an inch.

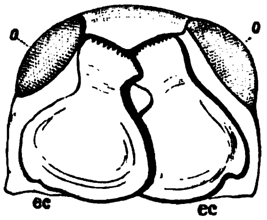

Fig. 8.

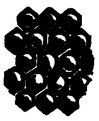

Fig. 8 *a*.

Fig. 8. Cast of the under side of the head of *Pt. bilobus*,[1] with the basal joints of the ectognaths (*ec*) in place; the large eyes (*o, o*) are also seen; Fig. 8 *a* represents a portion of one of the eyes greatly magnified.

The Body-segments.—The body, in well-preserved individuals, is barrel-shaped in front, the seven anterior or thoracic segments (8—14), taken together, measuring about 1¾ inch in length by 1¾ in greatest breadth. The thoracic somites in one specimen (Pl. X, fig. 3) measure 2¼ inches in length, but the length of the segments in this example are certainly above the average.

The anterior segments are extremely narrow in proportion to their breadth, being about five times as broad as they are long. When not crushed or distorted they are gently arched forward in the centre, whilst at the sides the anterior angles are produced forward into blunt lobes, the outer margins being oblique, and their posterior angles a little produced backward, particularly in the seventh thoracic segment (14). This general form of the thoracic segment will be observed in all the species of *Pterygotus* (see Pls. VIII, X, XI, XII, and XV).

The following five segments (15—19)—which are called abdominal—present a marked change from the preceding, becoming gradually narrower and longer; the first (15) being three or (at most) four times as wide as long; the fourth (18) hardly twice as wide as long; the fifth (19), or penultimate, is nearly equilateral, being only a very little wider than long; both the fourth and fifth somites are a little contracted in front, and have their lateral borders slightly curved and the posterior angles produced; the fifth somite (19) is carinated on its upper side, but only for its lower two thirds. The 'telson' or terminal segment (20) is 11 lines in length by 8 lines in breadth; it is carinated for a short distance at its upper end, whilst at its lower border it is deeply emarginated.

The outer margins of the body-segments and telson appear to be quite smooth, not serrated or crenated, as in several other species.

We are unable to give direct evidence of the thickness of the body-segments, as we did in the case of *Pt. anglicus* (see Part I, pp. 41 and 42); but there is little doubt that it was about the same in relative proportion to its bulk.

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[1] Copied from pl. i, fig. 4, of 'Geol. Surv. Memoir,' Mon. I, on the *Eurypteridæ*.

At first sight it would appear that the body of *Pt. bilobus*, var. *a*, was destitute of the characteristic markings discernible upon the larger examples of this genus; but such is really not the case, for although not always readily seen, they can, with the aid of a good pocket-lens, usually be detected upon some part of the body-segments. It consists in this, as in the larger, species of numerous small semicircular plicæ (the curve opening forwards, see Woodcut), which probably covered the anterior half of each segment, leaving the posterior destitute of ornament (see Pl. XIII, fig. 1*g*).

The head in this as in the other species is destitute of sculpture on its surface.

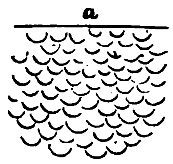

Fig. 9. Ornament on the segments of *Pt. bilobus*.
a. Anterior border.

We must now proceed to the examination of the under side of the head and the appendages.

Numerous specimens belonging to this species can now be seen and studied, both in the Museum of Practical Geology, Jermyn Street, and in the British Museum, in which many of the appendages still remain *in sitû*; whilst in other examples they are found displaced, but preserved upon the same slab with the entire body; from which it is evident they have become detached by the quiet dissolution of the softer muscular tissues of the animal.

In the accompanying Woodcut (p. 58) I have delineated, of the natural size, the oral appendages belonging to the entire specimen of *Pterygotus bilobus*, var. *a*, drawn upon Pl. X, fig. 3. These (by some slight movement in the fine, soft, clayey sediment in which the animal was enveloped) must have become separated from the rest of the body before decomposition had proceeded very far; for, although fractured and imperfect in detail (by reason of the present indurated character of the matrix), they still clearly prove that the entire buccal apparatus—held together by its integument—has thus been preserved to us.

The separate organs are represented as they lie upon the surface of the same slab of shale in which the entire body (Pl. X, fig. 3) is preserved. Their correct order and position may be readily understood by turning to Part I, Pl. VIII, fig. 1, where I have given a restored figure of the under side of the great *Pt. anglicus*, with its oral appendages in place. The *antennæ* (Woodcut, fig. 10, 1, 1; Pl. X, figs. 1, 2, *a*, *a*) are about 2¼ inches in length by ¼ inch in breadth at the base of the chelæ, the moveable ramus being about 8 lines long. Both the fixed and the moveable rami of the chelæ are slender; the former is slightly shorter than the latter; their points are sharply incurved; the inner borders are armed with minute teeth, which, like that of the larger species, vary in size, being at intervals marked by one much larger than the rest.

There appear to be five joints in the antennæ of this species, but it is seldom that their true line of articulation can be readily distinguished. Five are clearly to be seen in one of the antennæ figured in the accompanying woodcut, fig. 10.

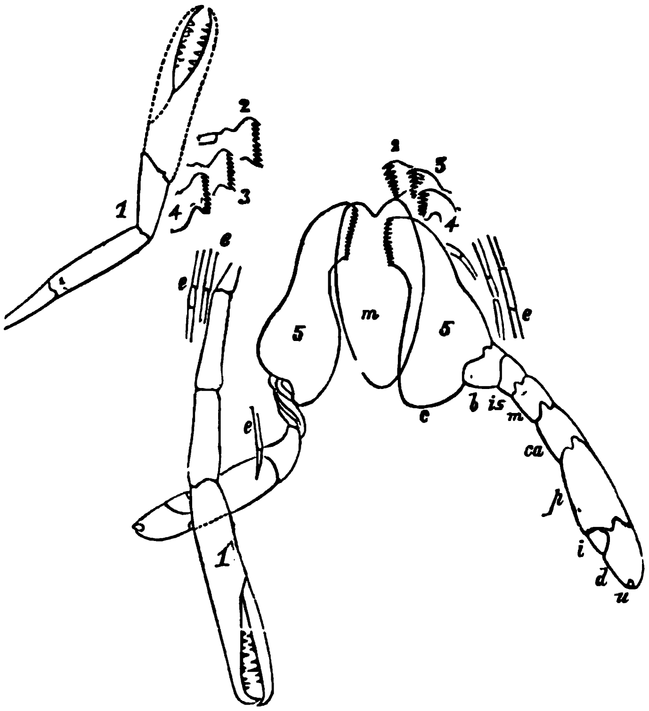

FIG. 10. Detached organs from the head of *Pterygotus bilobus* (var. *a*), figured in Pl. X, fig. 3.

1, 1. The chelate antennæ.
2, 2. The basal joints of the 1st pair of endognaths.
3, 3. „ „ 2nd „ „
4, 4. „ „ 3rd „ „
5, 5. The ectognaths, or maxillipeds.
m. The metastoma, or post-oral plate.
e, *e*, *e*. Portions of the filiform appendages of the endognaths.

The letters to the joints of the ectognath correspond with the articuli as enumerated in Part I, p. 6.

(The organs are here represented of the natural size.)

The first joint is 3 lines in length by 1·line at its proximal and 2 lines at its distal end in breadth; the second and third are each 6 lines in length and 2 lines in breadth; the fourth is 6 lines to the base of the articulation of the moveable ramus, the rami being 7 lines in length; the fifth joint is the moveable ramus already described.

The antennæ appear to have been epistomial organs like the inner antennæ of *Limulus* (see Part I, Pl. IX, fig. 1, 2); we have no evidence of their having been furnished with a mandible at their proximal end, as is the case with the succeeding four pairs of oral appendages, the endognaths and ectognaths. We shall, therefore, continue to consider their point of attachment to be anterior to the mouth, as represented in Part I, Pl. VIII, fig. 1, 2.

The Endognaths (which may be considered as equivalent to the mandibles and the first and second maxillæ of the higher Crustacea) are the next three pairs of oral appendages.

They present no marked variation in the size of their basal joints, although the length of the articuli of their palpi, no doubt, varies according to their anterior or posterior position in the series. The subjoined Woodcut (fig. 11) conveys a correct idea of the general form which they present. It is drawn from a detached specimen preserved in the British Museum.

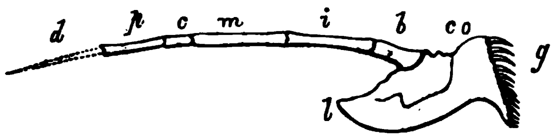

Fig. 11. Endognath of *Pterygotus bilobus.*

Two other and more perfect detached examples (preserved in the Museum of Practical Geology, Jermyn Street) are represented in Pl. XIV, fig. 3.

In general form they closely agree with the far larger endognaths of *Pt. anglicus* (see Part I, Pl. VII, figs. 5, 6, 7). The coxal joint (*co*) has a broad tongue-shaped lamina (*l*), for its attachment to the head, and is furnished along its inner free border with a row of about nine or ten sharp, curved teeth (*g*), which are longest in front and have the appearance of being articulated at their base to the border of the coxal joint; the palpus is articulated to the mandible on its upper border by a short joint (*b*), succeeded by two nearly linear joints of about equal length (*i* and *m*); the carpus (*c*), a very small articulation, is followed by the penultimate joint (*p*), corresponding nearly in length with the third and fourth articuli; to this is articulated the slender, tapering terminal joint (*d*). The length of the palpi varies; the longer of the two figured at Pl. XIV, fig. 3, measures 1 inch 7 lines from its articulation with the coxal joint to its distal extremity; the shorter measures 1 inch 4 lines, whilst that figured in our Woodcut (fig. 11) is 1 inch 9 lines long; the endognath (*e*) lying across the swimming-foot of the entire *Pterygotus* in Pl. X, fig. 1, measures 1 inch, 8 lines. Two endognaths—one *in sitû* on the left side of the head (*e*), and the other lying across the three anterior thoracic segments on the right side—are seen with the *Pterygotus bilotus*, Pl. X, fig. 2; whilst the basal joints of all three pairs of endognaths, and portions of their palpi, are seen associated together in the specimen figured in our Woodcut, fig. 10, on page 58.

The Ectognaths in all the species of this order represent (so far as we are acquainted with their appendages) the principal organs of locomotion and manducation.[1] They may be considered to be homologous with the first pair of maxillipeds in the higher Crustacea, and also to correspond with the last pair of appendages in *Limulus* (Pl. IX, fig. 1, 7). In the larval Decapod we find locomotion effected by the enlargement of two pairs of the maxillipeds, the true thoracic limbs being undeveloped, the abdomen being also destitute of appendages, thus affording another illustration among recent Crustacea of this palæozoic type of structure (see Pl. IX, fig. 7).

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[1] *Stylonurus* is the only genus in which we find *two pairs* of elongated swimming appendages. See 'Geol. Mag.,' 1864, vol. i, pl. x, fig. 1, p. 197; and 'Quart. Journ. Geol. Soc.,' 1865, vol. xxi, pl. xiii, p. 482.

The ectognaths in *Pterygotus bilobus*, var. *a*, differ but little in general form from those of the great *Pt. anglicus* described in Part I of this Monograph; they can be seen *in sitû* in figs. 1 and 2, Pl. X, and in the detailed drawing of the detached appendages of fig. 3 given in the Woodcut at page 58 (fig. 10).

The following is an enumeration of the several joints of this appendage:

1. Basal joint (*coxa*).—The great lower lobe is wide and of a spherico-triangular shape, the inner margins, as well as the outer and base, being all convex. The neck is suddenly contracted and short, and the serrated terminal lobe transverse or oblong, greatly oblique, and overlapping (in many specimens) the opposite edge.

Its toothed margin is curved and set with about thirteen small teeth.

The succeeding joints (which together make up the swimming-foot) are articulated to the posterior outer angle of the great lower lobe of the coxal joint.

2. *Basos*, short and broad linear.

3. *Ischium*, narrow, longest on the inner margin.

4. *Meros*, longest on the outer margin; lower border indented, forming an articulation for the—

5. *Carpus*, somewhat triangular in form, having its outer and longest border convex, and its upper edge produced so as to form a process by which it is more strongly articulated with the fourth joint.

6. *Propodos*.—With the exception of the great basal joint, this is the largest of any, being equal in length to the four preceding articuli. It is oblong, but contracted slightly at the upper end, so as to give a curved outline to its outer border; the upper or proximal end is doubly curved where it is articulated with the fifth joint; the inner lateral margin is nearly straight; the distal end is pretty deeply indented, so as to form a rounded notch for the reception of the terminal joint.

Between this joint and the terminal one there is what Prof. Hall has called[1] an intercalated triangular plate (see Woodcut, p. 58, fig. 10, 5, *i*), united to the border of the penultimate joint, and overlapping the oval terminal palette (see *antè*, Part I, p. 35).

Dactylos.—A regularly ovate palette, as broad as the penultimate joint, and nearly as long; it fits into the bilobed extremity of the sixth joint, and is held fast by its articulation with it, and by the overlapping of the intercalated triangular plate (*i*) already referred to.

This ovate palette is seen to be indented at its distal end, and into the indentation is inserted a minute plate (*u*) which Prof. Hall calls a 'terminal palette;' this cannot, however, be considered of greater importance than a spine or claw affixed to the distal extremity of the joint, like that seen on the tip of the modified antennule of the male *Limulus* (see Pl. IX, fig. 1 a), or on the extremity of the terminal oval palette of the swimming-foot of the recent *Scylla serrata.*

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[1] See 'Nat. Hist. of New York, Palæontology,' vol. iii, 1859, pp. 397 and 400, on *Eurypterus*, pl. 80 and nine following plates.

The Metastoma, or Post-oral Plate.—This cordate plate is found with all the species. Its position is naturally behind the oral aperture, enclosing, with its anterior bilobed portion, the inner mandibular borders of the great coxal joints of the ectognaths (see Pl. VIII, fig. 1 *m*; and Pl. X, fig. 2 *m*). It also remains associated with the detached oral appendages figured in our Woodcut, p. 58, fig. 10 *m.* Its impression can be faintly seen through the head-shield of fig. 1 in Pl. VIII. Its length varies from 9 to 11 lines, and its breadth is usually about 5 to 6 lines. The anterior portion of the metastoma sometimes displays upon its surface the characteristic semicircular plicæ seen so readily in all the larger forms (Pl. III, fig. 1; Pl. XIII, fig. 1 *e*; Pl. XV, fig. 3). This plate was, no doubt, attached to the head by its posterior border, which, in some specimens, is seen to be distinctly truncated at its lower end.

The Thoracic Plate, or Operculum.—The normal position of this plate is upon the ventral surface of the body, covering the under surface of the first two thoracic somites; it was attached along its anterior border to the posterior margin of the head; the rest of the plate was, no doubt, free, as in the recent *Limulus.*

I have somewhat fully described this plate in Part I, p. 39, and I shall have occasion to refer to it again when treating of *Pt. perornatus*, &c., so I will now only briefly describe its form in *Pt. bilobus.*

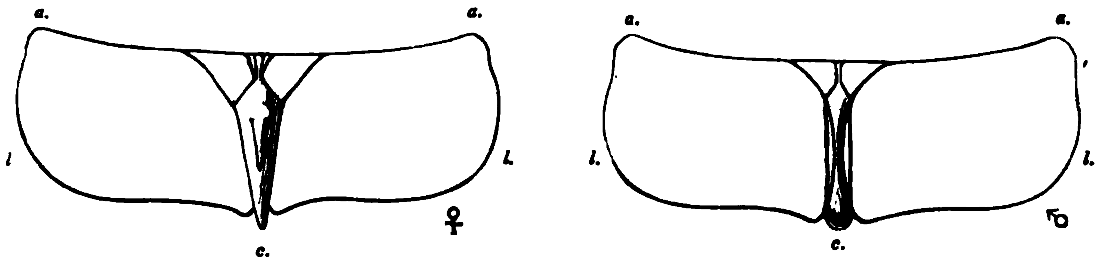

FIG. 12. Operculum of *Pt. bilobus*, var. α. (Two forms seen.)
a, a. Line of attachment to head. *l, l.* Lateral alæ. *c.* Central appendage.

It consists in this, as in all the other forms, of a median appendage and two lateral alæ. These alæ, which are sculptured upon their outer and under side, are equal in length to the first two thoracic segments, and in breadth correspond exactly with the segments which they overlie. They are united in the median line by a narrow central lobe (*rounded* at its distal free end in Pl. X, fig. 1 *c*, but *pointed* in Pl. X, fig. 2), hastate at its proximal end, which is directed forwards.

I have drawn these two forms of plates on the accompanying Woodcut (fig. 12), in order that they may be more clearly seen.

Probably these differences in form may be of sexual value, especially as the same portion of this plate is modified in the male and female of *Limulus* (see Pl. IX, figs. 1 and 1 *c*). I do not think them of specific importance.

Some excellent figures of *Pterygotus bilobus* will be found in pl. i, 'Memoirs of the Geol. Surv.,' Monograph I, 1859. In this plate are represented two entire examples, parts of three others, and several detached appendages belonging to *Pt. bilobus*, var. *α* (figs. 1—12). In pl. xv of the same work a diagrammatical restoration is given of this species, which, however, now needs to be corrected in accordance with the present more complete knowledge of its structure. Another segment should be added to the thoracic series, and between the chelate antennæ and the great ectognaths or maxillipeds, there should be three pairs of endognaths with simple palpi.

The true position of the thoracic plate or operculum has also since been satisfactorily made out.[1] (See Part I of this Monograph, Pl. VIII, fig. 1, &c.)

In pl. i, figs. 8 and 8 *a* (*op. cit.*), a very perfect swimming-foot of one of the ectognaths is represented having a long stylet (*t*) attached to the lower and inner border of the 4th joint (*meros*). This is evidently the palpus of one of the endognaths detached from its place and lying upon the surface of the swimming-foot of the ectognath, a very likely thing to happen when the appendages become detached from the head.

The other remains figured in this plate (except fig. 17, *Eurypterus lanceolatus*) belong to *Pterygotus bilobus* (var. *γ*, *perornatus*), to be presently described.

VAR. 2.—PTERYGOTUS BILOBUS, var. *β*, *crassus*. Pl. XI, fig. 1.

The specimen upon which this variety is founded is distinguished from var. *α* by the greater transverse breadth of the body-segments in proportion to their length, whilst the penultimate segment (19) and the telson (20) are as long and as well developed as in the preceding variety of this species.

Nor does it appear that any of the segments save the last thoracic (14) and the first abdominal (15) have been abnormally overlapped one above another by longitudinal compression after death.

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[1] These same corrections may be made in the first figure ever given by Mr. Salter, in Nov. 1855, 'Quart. Journ. Geol. Soc.,' 1856, vol. xii, p. 28; and in 'Siluria,' 4th edition, 1867, p. 162.

The following are the measurements of the body:

	Head,		1 inch 3 lines long,	and	1 inch 7 lines broad.
Thoracic.	Segment	(8)	2	,,	1 ,, 9 ,,
	,,	(9)	3	,,	2 inches broad.
	,,	(10)	3	,,	2 ,,
	,,	(11)	2	,,	2 ,, 1 line broad.
	,,	(12)	2	,,	2 ,, 1 ,,
	,,	(13)	2½	,,	2 ,, ... ,,
	,,	(14)	3	,,	1 inch 8 lines broad.
Abdominal.	,,	(15)	3	,,	1 ,, 2 ,,
	,,	(16)	2	,,	1 ,, 1 line broad.
	,,	(17)	2	,,	1 ,, ... ,,
	,,	(18)	3	,,	... 11 lines ,,
	,,	(19)	7	,,	... 10 ,, ,,
	Telson	(20)	11	,,	... 9 ,, ,,

In the example figured (Pl. XI, fig. 1) the ectognaths or swimming-feet (*ec*), are both *in sitû*, and the impressions of their great serrated basal joints (*s*) can be seen through the overlying head-shield. The thoracic plate, or operculum, with its pointed median lobe, can likewise be seen impressed through the anterior thoracic somites. One of the endognaths (*e*) and one of the chelate antennæ (*a*) are also seen detached from the head and lying on the left side of the body. The large compound eyes (*o*, *o*) can also be seen on the anterior border of the head-shield.

The dilated form of this specimen appeared to me so very extreme as compared with the great series of *Pt. bilobus*, var. *a*, which I have had the opportunity to examine, both in the British Museum and the Museum of Practical Geology, Jermyn Street, that I have thought it at least entitled to a passing notice.[1]

VAR. 3.—PTERYGOTUS BILOBUS, var. γ, *peromatus*. Pl. XI, fig. 2, and Pls. XIII—XV.

HIMANTOPTERUS PERORNATUS, *Salter*. Quart. Journ. Geol. Soc., 1856, vol. xii, p. 31, and p. 28, fig. 6.

PTERYGOTUS PERORNATUS, *Salter*. Mem. Geol. Surv., Mon. I, 1859, p. 45, pl. i, figs. 13—15, pl. xv, fig. 2.

— — var. *plicatissimus*. Ib., pl. i, fig. 16.

In my report to the British Association for the Advancement of Science (read before

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[1] In the 'Quarterly Journ. Geol. Soc.,' vol. xxiv, 1868, p. 295, I only spoke of three varieties of *bilobus*, viz. var. *inornatus*, *perornatus*, and *crassus*; it has since been found necessary to name a fourth variety, δ, *acidens*. (See also 'Report British Association,' Dundee, 1867, p. 44.)

Section C, at Dundee) in 1867, and printed in the volume for that year, p. 44, and also in the 'Quarterly Journal of the Geological Society' for 1868, vol. xxiv, p. 294, I pointed out the necessity of reconsidering the species of *Pt. bilobus* and *Pt. perornatus.*

Previously to 1865 *Pterygotus bilobus* had been found by Mr. Slimon in a nearly perfect state, being the first British species figured entire.

It obtained its specific name from the bilobed character of the telson; but at that time no complete example of *Pterygotus perornatus* had been met with.[1]

Since then *Pt. perornatus* has also been obtained whole, and is likewise furnished with a bilobed telson.

Difference in size cannot be relied upon as a means of separating these two, nor can the ornamentation be made use of as a specific distinction; the appendages are alike in both.

The thoracic plate or operculum is valuable, no doubt, as a means of separating such forms, but, unfortunately, it cannot often be seen.

I have therefore concluded to retain the name *bilobus* as the specific designation for all four forms described in this part, treating them as varieties only, until we can obtain more positive evidence of their specific distinctness than we at present possess.

That event arising, the specific name *bilobus* should be abolished, and the varietal appellations retained as of specific value. I do not, however, apprehend that such a necessity is likely to occur, the present tendency among naturalists being rather to diminish than to increase the number of species.

This is the largest form of *Pterygotus* found at Lesmahago, the almost entire example—figured in Pl. XIII, of one half of the natural size—being not less than 11½ to 12 inches in length and 3¼ inches in greatest breadth.

Figs. 1 and 2 in Pl. XV were parts of two individuals equally large, whilst the detached head and swimming-feet figured of the natural size on Pl. XIV would represent an animal 18 inches in length by 5 inches in breadth. If the detached chela (Pl. XI, fig. 3) belonged to this species, we have evidence of a form not less than 2 feet in length and probably longer.

Making a careful measurement of the body of *Pt. perornatus* figured in Pl. XIII, and aided by figs. 1 and 2 of Pl. XV, we get the following proportions for an individual about 12 inches in length:

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[1] The head and first six thoracic segments of a specimen as large as that figured on our Pl. XV are drawn by Mr. Bone in pl. i of the 'Geological Survey Memoirs, Monograph I.'

Thoracic.	Head	(1—7)	=	2 inches long	by	3 inches broad.		
	Segment	(8)	=	4 lines	,,	3	,,	2 lines broad.
	,,	(9)	=	8 ,,	,,	3	,,	3 ,,
	,,	(10)	=	9 ,,	,,	3	,,	4 ,,
	,,	(11)	=	9 ,,	,,	3	,,	2 ,,
	,,	(12)	=	9 ,,	,,	3	,,	2 ,,
	,,	(13)	=	9 ,,	,,	3	,,	2 ,,
	,,	(14)	=	8 ,,	,,	2	,,	6 ,,
Abdominal.	,,	(15)	=	8 ,,	,,	2	,,	2 ,,
	,,	(16)	=	9 ,,	,,	2	,,	0 ,,
	,,	(17)	=	9 ,,	,,	1	,,	10 ,,
	,,	(18)	=	10 ,,	,,	1	,,	6 ,,
	,,	(19)	=	1 inch	,,	1	,,	5 ,,
	Telson	(20)	=	1 ,, 9 lines	,,	1	,,	5 ,,

The head is nearly one third broader than long, semicircular in front, the large compound eyes forming prominent projections on the latero-anterior border about 10 lines in length. The facetted corneæ of the eyes in Pl. XIII, and of the detached head figured on Pl. XIV, 1 *b*, 1 *c*, can be distinctly seen with a good pocket-glass.

The larval eye-spots, or ocelli, are also clearly seen in the centre of the carapace of all the specimens figured.

The surface of the carapace is destitute of squamate markings or any other kind of ornamentation whatsoever; but the surfaces of the coxal joints of the ectognath (Pl. XIV, fig. 1 *c*) and the cordiform metastoma, or post-oral plate, are both highly ornamented with squamate markings (Pl. XV, fig. 3).

The chelate antennæ belonging to the specimen figured in Pl. XIII are 4½ inches in length, and the chelæ are 5 lines broad. The length of the movable ramus of the chela is 1 inch; the inner border of both rami are closely planted with large and small sharply pointed teeth. They closely resemble in form the antennæ of var. *a* already noticed.

The endognaths agree in form with the previously described organs of var. *a*. The woodcut figure of a detached endognath given at page 59 (fig. 11) probably belongs to this variety, with which its size well agrees.

The metastoma or post-oral plate (Pl. XIII, figs. 1 *a*, *m*, and 1 *c*; Pl. XIV, fig. 2;[1] and Pl. XV, fig. 3) is oblong oval, deeply bilobed in front, and slightly truncated along its posterior border. It is closely covered, especially upon its anterior and bilobed portion, with minute squamate markings. The detached lip-plate (fig. 3, Pl. XV) is 2 inches 4 lines long and 1¼ inch in breadth near the centre, representing an individual not less than 18 inches long.

Although the thoracic plate or operculum is discernible in the specimen figured in

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[1] This lip-plate belongs to the specimen figured in Pl. XIII, which was thus figured twice by mistake.

Pl. XIII, where the anterior thoracic segments are displaced, yet its exact contour cannot very well be represented.

The anterior body-segments are much arched forward in the centre; the lateral area is recurved as in the other species; and the anterior border appears to have projected under and formed an articulation with the preceding segment (see Pl. XV, fig. 1, segments 9 and 10).

The sculpture of the body-rings (Pl. XIII, fig. 1 *g*) extends over less than half their surface.

The plicæ are open forwards, very small, often almost linear on the front margin, and the remainder are less than semicircles. The anterior border of the segments is rounded off and smooth. A transverse faintly impressed line separates the anterior sculptured half from the posterior smooth portion; but this is not always seen. The lateral borders of the segments are not crenated.

The telson (Pl. XV, fig. 2, 20), is bilobed in form like the preceding varieties α and β; and the penultimate segment has its anterior border contracted, its sides curved, and its posterior angles produced in a similar manner.

On the Branchiæ in Pterygotus.—The determination by Dr. James Hall, in America, of the true position of the thoracic plate or operculum in *Eurypterus*,[1] having since been fully confirmed with regard to the British species of *Pterygotus*,[2] *Slimonia*,[3] and *Eurypterus*,[4] and also its homology with the operculum in *Limulus* (Pl. IX, fig. 1, 1 *a*)—beneath which are placed the respiratory organs—it was reasonable to expect to find evidence of branchiæ in *Pterygotus* also, considering the wonderful state of perfection in which many of the remains of this genus have been preserved.

But it was not until 1867 that I obtained satisfactory evidence of their existence. I first drew attention to them in my 'Third Report to the British Association on the Structure and Classification of the Fossil Crustacea,' at Dundee, in September of that year, and I have since published figures of some detached leaflets in a paper read before the Geological Society in March last.[5]

I first detected them associated with the specimen figured in Pl. XII, figs. 1 *a* (*br*) and 1 *d*; next in that in Pl. XIII, figs. 1 *a* and 1 *h*. When at Dundee (in 1867), I obtained from Mr. Slimon a portion of shale having several detached leaf-like organs preserved upon it,[6] corresponding in form and surface-markings with those referred to above, and which occur with specimens of entire *Pterygoti* and lying in such a position upon the slabs as to leave little doubt that their normal place of attachment would be under the thoracic plate or operculum, as in the recent *Limulus*.

[1] Hall, 1859, 'Geol. Surv. New York,' "Palæontology," vol. iii, pp. 392—413.

[2] H. Woodward, 1867, 'Quart. Journ. Geol. Soc.,' vol. xxiii, pp. 28—37, pls. 1 and 2.

[3] Ditto, 'Intellectual Observer,' 1863, vol. iv, pp. 229—237.

[4] Ditto, 'Geol. Mag.,' 1864, vol. i, pp. 107—111, pl. v, fig. 8.

[5] 'Quart. Journ. Geol. Soc.,' 1868, vol. xxiv, p. 294, pl. x, figs. 3 *a*, 3 *b*.

[6] The same which are figured in the 'Quart. Journ.' above referred to.

But there is yet another specimen, which seems to complete the evidence of the position of these branchial plates in *Pterygotus*.

I allude to a specimen described in the 'Memoirs of the Geol. Survey,' Monograph I, p. 49, under the name of *Pt. perornatus*, var. *plicatissimus*. One of the body-rings is there figured, *loc. cit.*; and the anterior portion of the specimen is represented in pl. i, fig. 16, of that work. We have figured the whole of the same specimen of the natural size in Pl. XI, fig. 2 *a*, and the anterior portion enlarged twice the natural size in fig. 2 *b*.

Mr. Salter writes as follows:—"The carapace[1] is much compressed longitudinally, but the true form would probably be a full semioval; the position of the eyes is obscurely marked. The surface is covered with semicircular plicæ,[2] the curves of which open backwards (contrary to the usual position over the rest of the body). In front is seen the impression of the large ovate median lobe of the epistoma,[3] shaped as usual, and behind are two radiated muscular impressions[4] placed low down on the carapace and towards the median line, which impressions are probably the attachments of the great swimming-feet."

In another place (p. 45) in the same description he observes:—"The head (carapace) was formerly described by me as smooth, but in better specimens it is closely and fully sculptured, the plicæ convex *forwards*." It is evident that Mr. Salter here refers to this same specimen (Pl. XI, fig. 2); for although I have carefully examined all the heads of *Pterygotus perornatus* within my reach, I have been unable to detect any sculpture on the head-shield, nor, indeed, does it exist upon the carapace of this or of any other species of this genus. The fact, then, of the portion here referred to (fig. 2 *b*) being sculptured precludes us from considering it as the head-shield. With regard to the direction of the squamate markings having their "plicæ convex *forwards*," and the curves open backwards, as this would be obviously contrary to every other known specimen of *Pterygotus* showing sculpture, we are at once enabled to perceive that this portion belonged to the under side of the body of fig. 2 *a*, and has been squeezed forwards as well as much compressed. This explains the difficulty of the reversed direction of the squamæ.

Mr. Salter has called the central appendage (figs. 2 *a* and 2 *b* (*c*, *c*)) "the large ovate median lobe of the epistoma, shaped as usual." This most satisfactorily settles the question of the nature of this anterior displaced organ of figs. 2 *a*, 2 *b*. The plate at that time (1859) described as the epistoma, or conjoined epistoma and labrum, is now known as the thoracic plate or operculum; *c* is its central appendage, and *op*, *op* are the two broad lateral wings, closely covered with squamæ.

But that which is of the greatest interest to us in this specimen (as bearing upon the question of the position of the branchiæ), is that between the curved and squeezed-up

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[1] The portion so called is seen in our enlarged figure, Pl. XI, fig. 2 *b*.

[2] See the lateral portions of fig. 2 *b*.

[3] Pl. XI, figs. 2 *a* and 2 *b*, letter *c*.

[4] Ibid., letters *br*, *br*.

operculum and the anterior border of the foremost body-segment there are preserved undoubted remains of branchial plates, figs. 2 *a* and 2 *b*, *br*, *br*, presenting the same delicate leaf-like vascular appearance as is seen in the specimens figured in Pls. XII and XIII.

These delicate membranous plates in *Pterygotus* differ in form from the corresponding organs in *Limulus;* but there is no doubt they occupied the same relative position. In *Limulus* the vascular striæ are parallel to the circumference of the lamellæ; in *Pterygotus* they appear to have branched and subdivided from the centre to the margin of the plate, becoming finer and more numerous towards the border.

As I shall have occasion to refer again to the branchiæ in the genus *Slimonia*, I do not propose to enter more fully upon their description here, especially as I hope shortly to have executed some carefully prepared figures of the respiratory organs of *Limulus* and other recent lamellibranchiate Crustacea for illustration and comparison.

In the details of the ornamentation and in the form of the body-segments this specimen (Pl. XI, fig. 2 *a*) agrees with that figured in Pl. XIII, fig. 1 *a*.

VAR. 4.—PTERYGOTUS BILOBUS, var. δ, *acidens*. Pl. XII.

This specimen, to which we have had occasion already to refer when speaking of the branchiæ of *Pterygotus*, is full of interest. It is preserved in the Museum of Practical Geology, Jermyn Street.

We see the head, with its great compound eyes (*o*, *o*), and its lateral eye-spots (*l e*), its chelate antenna (*a*), its great ectognaths or swimming-jaw-feet (*ec*), its metastoma or post-oral plate (*m*); the thoracic plate or operculum (*op*), with its branchiæ (*br*); and all the segments present (save 15 and 16, which are indicated with a lighter shading), including the broad bilobed telson (20).

The general outline of the body is globose, probably more so in proportion to its size than any example of var. *perornatus*. The dimensions are as follows :—

			long.		broad.		
	Head	(1—7)	15	lines by	2	inches.	
	Body-segment	(8)	4	„	2	„	
Thoracic.	„	(9)	6	„	2	„	2 lines.
	„	(10)	7	„	2	„	4 „
	„	(11)	6	„	2	„	6 „
	„	(12)	5	„	2	„	6 „
	„	(13)	5	„	2	„	5 „
	„	(14)	4	„	2	„	2 „
Abdominal.	„	(15)	6?	„	1	„	9 „ ?
	„	(16)	6?	„	1	„	7 „ ?
	„	(17)	6	„	1	„	4 „
	„	(18)	6	„	1	„	4 „
	„	(19)	9	„	1	„	... ...
	Telson	(20)	15	„	1	„	1 line.

The surface of the head is not ornamented in any way, but the bases of the jaw-feet, the thoracic plate (see Woodcut, fig. 13), and the anterior third of the body-segments, are closely covered with minute plicæ.

The portion of magnified scale-markings drawn by Mr. Hollick in Pl. XII, fig. 1 *c*, are from the body-segment (10); the squamæ are so close together that they actually present the appearance represented, but there is no real overlapping of scales, only a mimetic resemblance to it. Along the anterior border the scale-markings are very fine, closely packed, and but little arched; lower down they become more acute and considerably larger; whilst on the lateral borders they are extremely minute and packed very close together. The edges of all the segments are very minutely serrated, as in the larger Devonian species. The thoracic plate, which is very well preserved, is about 2 inches in breadth by about 10 lines in length.

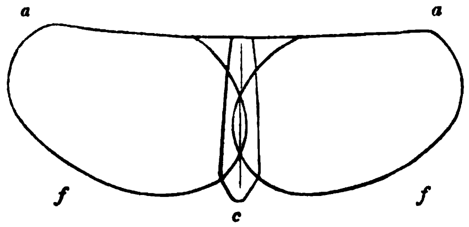

Fig. 13. Thoracic plate or operculum of *Pt. bilobus*, var. δ.[1]
a, a. Line of attachment to posterior border of head-shield. *f, f.* Free border. *c.* Central appendage.

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[1] The representation of the operculum in Pl. XII, fig. 1 *e*, is not quite correct. This Woodcut conveys a better idea of its form.

There is little doubt but that we have in this species evidence of a second and more membranous thoracic plate lying within the outer one, but its border is but ill defined in our plate.

The branchiæ are more distinct in this than in any specimen I have seen.

The largest leaflet is 8 lines in length by 4 lines in breadth; the smaller are 4 lines in length and 2 lines wide.

The chelate antennules in var. δ (Pl. XII, fig. 1 *b*) are distinguished from the ordinary form of *bilobus* by the more regular denticulation of the chelæ, and by the larger size of the terminal joint.

Length 1 inch 7 lines, breadth 4 lines; length of moveable ramus of chelæ 13 lines.

The metastoma, or post-oral plate, does not appear to be truncated posteriorly, as in var. *perornatus*, and is somewhat more oval and less elongated; and the emargination of the anterior border is much more slight.

Length 15 lines, breadth 10 lines.

Both ectognaths are preserved entire, and the serrated edges of their great basal joints are seen pressing through the head-shield, just in front of the larval eye-spots. The free swimming-foot attached to the coxal joint measures 1½ inch in length, and the penultimate joint (which is the widest) is 4½ lines in breadth.

It exhibits the same small intercalated triangular plate at the point of attachment of the dactylos with the propodos, and the former has at its distal extremity the same minute terminal palette, or unguis, common to the other species of *Pterygotus*.

This, together with all the foregoing varieties described in this Part, are from the Uppermost Silurian of Lesmahago, Lanarkshire.

A MONOGRAPH

OF THE

BRITISH FOSSIL CRUSTACEA

OF THE

ORDER MEROSTOMATA.

PART III.

Genus 1.—Pterygotus, *Agassiz.—Continued.*

Species 3.—PTERYGOTUS RANICEPS:—H. Woodward. 1868. Pl. XVI, fig. 1.

Pterygotus raniceps, *H. Woodward.* Quart. Journ. Geol. Soc., 1868, vol. xxiv, p. 294, pl. ix, fig. 3.

Our knowledge of this species is confined to a single specimen obtained, like the preceding one, by Mr. Robert Slimon from the hard flaggy shales (Upper Silurian) of Logan Water, near Lesmahagow, Lanarkshire (see pages 46—52).

Head-shield obtusely triangular. Eyes prominent, marginal. Breadth of posterior border of carapace 6 lines; greatest length 4½ lines, from posterior border to eyes 3 lines; breadth of carapace at eyes 3½ lines; diameter of eye 1 line.[1] A small depression marks the centre of the carapace between the eyes, and a small elevation may be seen slightly posterior to them, also on the median line. Larval eye-spots not visible. Length of the six segments 7½ lines, greatest breadth 9 lines; no ornamentation is preserved upon any part of the integument.

The specimen here described and figured is preserved in the British Museum.

REMAINS OF PTERYGOTUS FROM THE WEST OF ENGLAND.

The following *seven* species[2] are given upon the authority of Mr. J. W. Salter, the late eminent Palæontologist to the Geological Survey, who had devoted many years to the investigation of this group; namely:

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[1] This tubercle probably marks the position of the ocelli.

[2] An eighth species, *Pterygotus punctatus*, Salter, has, since its publication, been determined to belong to the genus *Eurypterus* (see 'Quart. Journ. Geol. Soc.,' 1868, paper by H. Woodward, "On some New Species of Crustacea," &c., vol. xxiv, p. 290, plates ix and x).

PTERYGOTUS BANKSII, *Salter*. U. Ludlow Rock and Passage-Beds, Ludlow, Whitcliffe, &c.
— TAURINUS, *Salter*. U. Silurian, Ewyas-Harold, Herefordshire.
— LUDENSIS, *Salter*. Old Red Sandstone, Ludlow, Trimpley, &c.
— GIGAS, *Salter*. Downton Sandstone and Passage Beds, Kington, Hereford.
— PROBLEMATICUS, *Salter*. U. Ludlow Rock, and Passage Beds, Whitcliffe, Ludlow Cornstones, Old Red Sandstone, &c.
— ARCUATUS, *Salter*. L. Ludlow Rock, Church Hill, Leintwardine.
— STYLOPS, *Salter*. U. Silurian, Kington.

With the exception of *Pterygotus Banksii*, they are founded upon well-marked fragments only—which, however decisive as to their specific distinctness, need further confirmation by the discovery of more perfect remains.

Save in a few instances, therefore, it has not been thought desirable to redraw these detached portions, but rather to refer the reader to the large series of remains figured in the Geological Survey Monograph by Messrs. Huxley and Salter, and to reprint the descriptions of species as given by the latter,[1] merely correcting any obvious errors and making such few additions as we are enabled to do with confidence by our increased acquaintance with the more complete examples from other localities.

Should more perfect remains be discovered, as there is every encouragement to hope may be the case, we may yet, at some future day, figure as entire examples of these West of England *Pterygoti* as we have been enabled to do of those from beds of the same age in Scotland.

Species 4.—PTERYGOTUS BANKSII:—Salter. 1859. Pl. XVI, figs. 2—6.

HIMANTOPTERUS BANKSII, *Salter*. Quart. Journ. Geol. Soc., 1856, vol. xii, p. 32 and p. 99, pl. ii, fig. 5.
— — Siluria, 2nd ed., 1856, p. 266, foss. 66, fig. 1.
PTERYGOTUS BANKSII, *Salter*. Mem. Geol. Surv., Mon. I, 1859, p. 51, pl. xii, figs. 22—46.
— — Siluria, 3rd edit., 1859, p. 540.
— — Ibid., 4th edit., 1867, p. 239.

Named in honour of Richard Banks, Esq., of Kington, Hereford, who has made rich collections of the *Pterygoti* of that locality.

This small neat species, of which there are many specimens, both in the British Museum and in that of the Museum of Practical Geology, occurs with *Pterygotus gigas*, and spines both of Crustacea and fish, in the yellow tilestones[2] (Downton Sandstone) beds of Kington, Herefordshire. It is associated with the *Platyschisma helicites* and *Lingula cornea* (Sil. Syst.). These are the two species of shells which accompany the fossils of Lesmahagow above described; a good argument, therefore, even without other evidence, for regarding these Lesmahagow beds as the uppermost portions of the Ludlow rocks.[1]

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[1] If we omit *Eurypterus* (*Pterygotus*) *punctatus* (which occupies nearly two folio plates, and has twenty-eight figures devoted to its illustration), and *Pt. taurinus* (which was not published until 1868), the six remaining species occupy four folio plates and are illustrated by ninety-seven figures; all are in a very imperfect state of preservation, and consist only of detached plates and appendages.—H. W.

[2] Referring to this term the Rev. W. S. Symonds, M.A., F.G.S., Rector of Pendock, near Tewkesbury (who has paid especial attention to the geology of this district), writes as follows:—" The word 'tilestones'

The full size must have been from four to five inches long, but the specimens usually met with would probably not be above three or four inches. One or two show the connection of the body-rings with the head (Pl. XVI, fig. 5) and appendages, or with the tail joints (fig. 4). None are quite complete, and though we have nearly all the parts they are usually disjointed.

The carapace (Pl. XVI, figs. 2 and 3) is a broad semioval; its length is as six to seven, except when lengthened or shortened by pressure. It is regularly convex, a little produced in front, smooth, and bears the small oval eyes rather more than half way up the head. They are much smaller than in *Pterygotus bilobus*, being not above one fourth the length of the carapace, and very convex.

The body is at first wider than the head, and then tapers backwards (Pl. XVI, fig. 5). The first ring is very narrow; the second twice as broad, and with the usual dilated extremities; the third, fourth, and fifth somites strap-shaped, arched in the middle, and direct on the sides, so that the segment appears much bent. The ends are truncate, in the anterior rings widest behind, and in the posterior ones tapering backwards.

The hinder rings (Pl. XVI, fig. 4) become gradually less transverse, the eleventh only two and a half times wider than long, and the twelfth above once and three quarters its own length.

The caudal joint (telson) differs, in its expanded form, materially from that of *Pterygotus bilobus*. It is about three fourths as long as wide; narrow at the base, with two short ridges running down from either angle; then expanded with somewhat convex sides towards the wide subtruncate apex; the outer angles are rounded off, the terminal notch shallow, and a short median keel continued from it one third up the segment.

The sculpture of the head is not known. On the body-rings a transverse lineation, running into open plicæ on the sides, occupies the front margin for not quite half the segment; a few plicæ are intermixed with the lines.[2]

(now happily abandoned by Sir R. I. Murchison) is altogether inappropriate as applied to the Ledbury rocks. There is not a stone capable of being formed into a *tile*, from the Downton sandstone to the Cornstones of Wall Hills; but there are thin muddy marls over the Downton beds, which would have been tilestones had they sufficiently hardened, and which are doubtless the equivalents of the true tilestones. I consider, therefore the term 'passage-rocks,' as used by Sir R. Murchison in the last edition of 'Siluria' to be the more appropriate appellation for these transition beds, and one which allows to the palæontologist as well as the physical geologist, a broad margin for the line of demar ation between the two great epochs of the Silurian and the Old Red." ('Quart. Journ. Geol. Soc.,' Lond., 1860, vol. xvi, pp. 193—197.)

[1] 'Quart. Journ. Geol.,' vol. xii, 1856, p. 32. See also Part II of this Monograph, pp. 46—52.

[2] On a caudal joint (pl. xii, fig. 46, Mem. Geol. Surv., Mon. I) a lineation, parallel to the outer border,

The *Antennæ* (Geol. Surv. Mem., Mon. I, pl. xii, figs. 30 and 40) are remarkably slender and straight; the base is large and broad, suddenly attenuated into the shaft, which is only a tenth of an inch wide, and three quarters of an inch long, beset with close small teeth, and furnished with three larger conical ones nearly straight; the central one as long as the width of the shaft. In the fragment of an antenna figured by Mr. Salter (Mon. I, pl. xii, fig. 40) from the Ludlow Rocks, the intermediate teeth are a little longer in proportion.

Ectognaths.—The basal joints are flask-shaped, much more elongate in the neck than those of *P. bilobus*, and less swelled at the base. [It is possible, Mr. Salter adds, they may not belong to this species at all, but to *Eurypterus linearis*, a species which occurs in the same beds; we do not yet know this joint in *Eurypterus*.[1]] The base is subquadrate, quite rectangular on the outer upper margin; the notch for attachment of the other joints is immediately beneath this angle, and tapering into the long neck, which has a sharp ridge posteriorly, and, together with the terminal lobes, equals the length of the basal portion. The teeth are minute.

The *Swimming-foot* (Pl. XVI, fig. 5) has a characteristic shape; the upper joints (fourth and fifth) are rather narrow; and the penultimate (*p*), instead of being simply conical, as in *Pt. bilobus*, is ovate, with the outer border especially convex. It is notched above to receive the fifth joint, and below divided into very unequal lobes. The terminal palette (*d*) is true oval, rather blunt at its origin, and more pointed at the extremity. It is nearly equal to the penultimate joint in length, but considerably narrower.

The *Post-oral plate* (Pl. XVI, fig. 6) differs a little in shape, but not specifically, unless the greater amount of ornament in some specimens be considered sufficient to separate it. The shape is elongate oval, the greatest width is at the upper third, the base is subtruncate, the apex has a shallow obtuse notch. At the lower fourth there is evidently a tubercle of attachment, and such as occurs in a more linear shape in other species. [It is desirable to find out the post-oral plate of *Eurypterus*, which is probably very similar.]

The sculpture is very conspicuous over the upper half; it consists of nearly straight or very slightly curved plicæ arranged in arched lines, and ending abruptly against the outer margin. In the sandstone specimens the sculpture does not extend so far down, but it is identical in structure.

Localities.—Upper Ludlow Rock, Ludlow Lane, Whitcliffe (and Batchcot?), Parlan, exterior slope of the Woolhope Valley (Mus. P. G.), Kington, Herefordshire (Mr. R. Banks' cabinet), Passage Beds, Ludlow Railway cuttings (cabinets of Messrs. Lightbody and Marston, Ludlow Museum, British Museum, and Museum of Practical Geology, Jermyn Street.)

is distinct, but it is uncertain if this specimen be of the same species; it has a strong median groove down the under side, and is less expanded in form than *P. Banksii.*

[1] Several of these minute detached basal joints are figured by Mr. Salter (see Mem. Geol. Surv., Mon. I, pl. xii, figs. 29 and 29*a*), but as they present no character of importance, and as their connection with *Pt. Banksii* seems doubtful, we have not thought it needful to reproduce them here.—H. W.

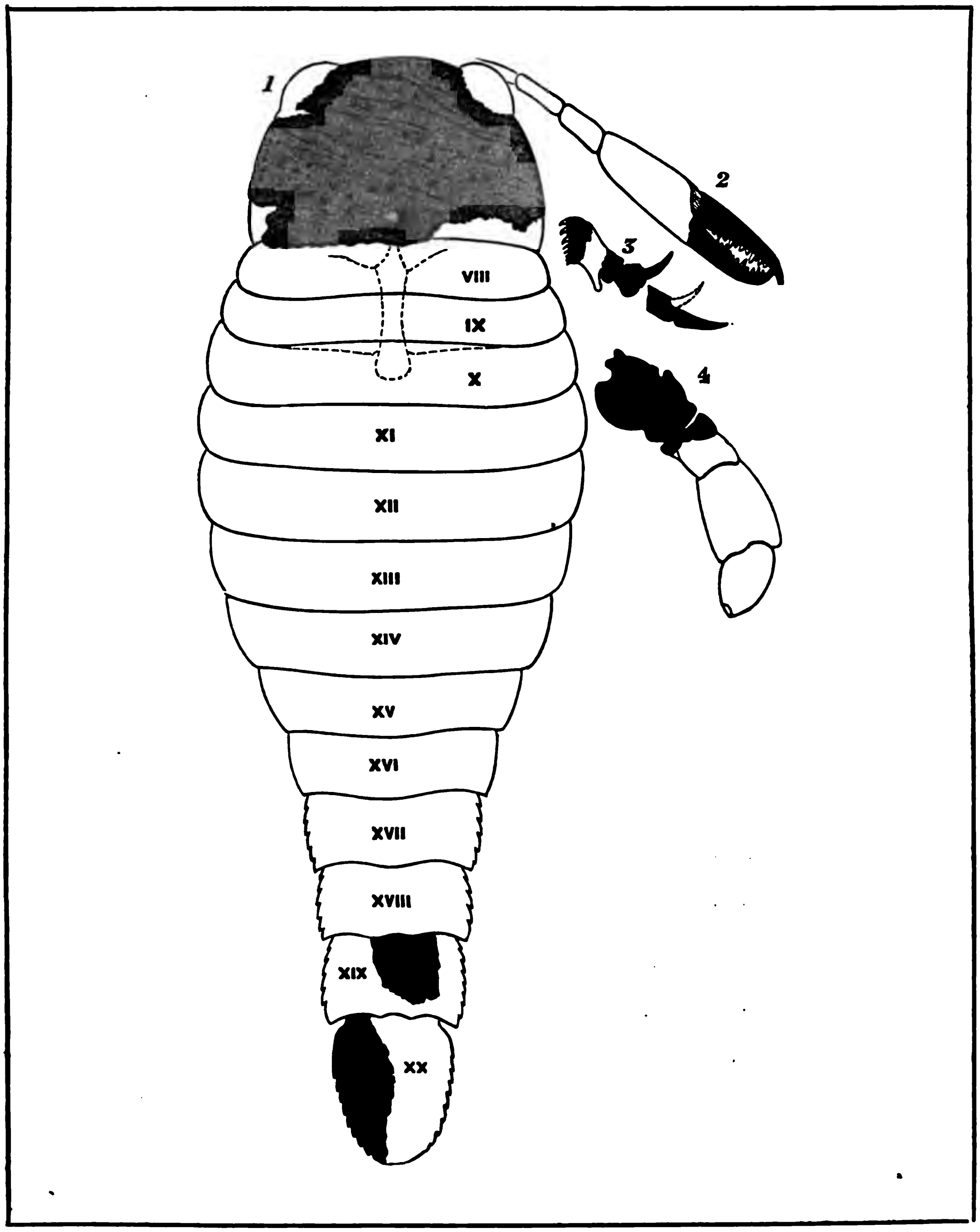

FIG. 14.—*Pterygotus taurinus*, Salter. Ledbury series, Ewyas Harold, Herefordshire. After a sketch by Mr. J. W. Salter, F.G.S. (For description see page 76.)

The shaded parts, namely, 1. the head-shield; 2, the chelate antenna; 3, the endognath; 4, the ectognath, or swimming-foot; and parts referred by Mr. Salter to the penultimate segment (XIX); and the last segment or "telson" (XX); are alone preserved.—H. W.

Species 5.—PTERYGOTUS TAURINUS:—Salter. 1868. Woodcut, Fig. 14, p. 75.

PTERYGOTUS TAURINUS, *Salter*. Report Brit. Assoc., Norwich Meeting, 1868. Trans. of Sections, p. 78.

This new species was obtained from the lowest Old Red, or Ledbury Shales formation. It is a very large one, and must have measured 7 feet in length when perfect. Its head is very square; the base of the swimming-foot small in proportion to that of other species. The chelate antennæ have the apices very greatly hooked and the teeth close. Only fragments of the body-rings have been found. The tail-joint appears to have been oval. The specimens were found at Ewyas Harold, and are in the cabinet of Dr. McCullough, of Abergavenny.

The Woodcut, given on page 75, is reproduced from an original sketch by the late Mr. J. W. Salter, drawn at the time his note was written. The parts known only are shaded; the outline was intended by Mr. Salter to convey an idea of the general form.

Measurements given by Mr. Salter:—

1. Head a foot wide.
2. Portion of chelate antennæ preserved, 6 inches long.
3. Portions of two palpi, 4 inches.
4. Basal portion of swimming-foot, 5 inches.

Species 6.—PTERYGOTUS LUDENSIS:—Salter. 1859. Pl. XVI, figs. 7—9.

PTERYGOTUS LUDENSIS, *Salter*. Mem. Geol. Surv., Mon. I, 1859, p. 79, pl. xiv, figs. 1—13; pl. ix, fig. 18?; pl. xii, figs. 1—5 (and 6?).
— — *Salter*. Siluria, 4th edit., 1867, p. 140, and p. 238.

Under this name Mr. Salter describes, with but little doubt of its specific distinctness, the fragments of a fine species very abundant indeed in the transition beds of Ludlow, shown as they are in the railway cutting near that town. All the specimens are in the cabinets of Mr. Lightbody and his son. The same species is found at Trimpley, near Kidderminster, and we are indebted to the late Mr. G. E. Roberts for the means of illustrating some points not clear in the specimens at Ludlow.

The materials consist of several body-rings[1] of a large size (Pl. XVI, figs. 7 and 8); a fragment of the caudal joint;[2] a specimen showing nearly all the body-joints and telson in position, but a good deal obliterated; the serrate basis of the swimming-feet, mandibles with palpi, antennæ; and to these must be added the post-oral plate, the bilobed

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[1] Mem. Geol. Surv., Mon. I, pl. xiv, figs. 2, 3, 4, 11: these are all fragments merely.—H. W.

[2] Ibid., fig. 12; only a fragment.

" (abdominal ? appendages,"[1] and possibly a portion of a swimming-foot, together with an imperfect caudal joint. (Mem. Geol. Surv., Mon. I, pl. xii, figs. 4—6.)

The two last may, however, belong to *P. gigas*, a species very nearly allied, and to which (says Mr. Salter) for some time I believed the whole of the specimens referable. Again, there is so much resemblance in certain points to the Scotch species, *P. anglicus*, that it requires nice discrimination to separate the three forms. The characters of the antennæ, and also of the caudal joint, will, I think, be sufficient. And if subsequent observation should tend to show that this "Tilestone" species is the opposite sex of the *P. gigas*, it will still have been worth while provisionally to separate them.

Body-joints.—The complete specimen (Pl. XVI, fig. 7) shows that the body was not greatly elongated, the segments being all rather widely transverse, the eighth, for instance, being fully four and a half times as wide as long; the ninth and tenth are gradually narrower, but the eleventh still shows a width two and a half times greater than the length, while in *P. anglicus* the corresponding joint appears to have been no more than one and a half times the length.

The penultimate joint is squareish, or rather inversely conical, not much expanded below. It is about one fourth wider than long, as in *P. anglicus*, and this at the hinder part only. A strong central keel runs down its whole length, covered with large squamæ, and the margins are similarly ornamented. (See Pl. XVI, fig. 8.) If the caudal joint (Mem. Geol. Sur., Mon. I, pl. ix, fig. 18) be of this species, it has lost the terminal apiculus. It is nearly elliptical, the base truncated. It is fully four inches long.

The sculpture of the body-rings consist of open semicircular squamæ, flattened along the anterior border and more convex behind, occupying the anterior half of the segment in the front rings, and more in the hinder ones, till, in the ninth and tenth, they nearly cover the segment. On the sides they are more elongated, and, as in other species (*P. gigas*, for instance), those on the upper side are more elongate and pointed than those on the lower. All the plicæ are prominent and sharp-edged. There are very few intermediate ones, but the surface of the cuticle is generally roughened between the plicæ. Some segments show the plicæ very large, and must have been at least fourteen inches broad. Other specimens in the Ludlow Museum show four or five rings overlapping, and some are subcylindrical, and with sharp edges. The caudal joint is broad-oval and shortly apiculated, less abruptly so than in *P. anglicus*, which, too, has a less regularly oval form, the greatest breadth being below the middle. It is marked all the way down dorsally by a strong carina covered with broad squamæ, and the edges are also squamate in two or three rows. In the specimen from Trimpley, the sides are marked by oblique radiating interrupted lines.

The *Thoracic plate* ("Epistoma and Labrum," Salter) is as large as that of *Pt. anglicus*, and nearly like it in all its parts.

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[1] These are still undeterminable; they may be cephalic, or thoracic appendages, they are clearly *not* abdominal; they probably do not belong to this genus at all: see figures 25—27, page 91.—H. W.

Antennæ.—These resemble in general form those of *P. anglicus,* but have a more slender shaft, tapering more quickly and narrower and with more conical teeth. The teeth are intermediate in form between the species above mentioned and *P. problematicus,* the central one being long-lanceolate, and the secondaries narrow, conical, and with coarse striæ. The base of the fixed claw is furnished with a set of stiff spines, as in *P. problematicus,* but the whole chela is proportionably much shorter.

Endognaths.—Of these there seem to be *three* pairs, as in *P. anglicus,* and of very similar shape. The joints of the palpus, like those of *P. gigas,* have a squamose ridge, along each side, and the ends of the joints are bilobed. The second joint is three and a quarter times as long as broad. This is nearly the proportion in *P. anglicus,* where it is three times the breadth. (See Woodcut, below, Fig. 16.)

The other pairs of jaws have their anterior margin more curved, and the teeth set on a more convex edge than in *P. anglicus.* The first tooth is set more backward, thick, and curved at the base, and all are more curved than in the Scotch species.

The *Post-oral plate* may belong either to this or to *P. gigas* (see Woodcut, Fig. 18, p. 84).

Base of Swimming-foot (Pl. XVI, fig. 9).—These portions are very characteristic in all the species. In this the shape most nearly resembles that of *P. gigas,* and the teeth are short and blunt, as in that species, but the neck is shorter. From *P. anglicus,* the shorter form, the short neck, blunt teeth, and convex upper lobe overhanging the teeth distinguish it; but the sculpture raised into thick, prominent, boss-like plicæ is almost identical. The lower edge is tuberculate, and even spinous; our figure does not show this part. A little comparison of this specimen with *P. anglicus* will show that both in the upper or front edge and on the lower or hinder edge the terminal lobe is more prominent in *P. ludensis.*

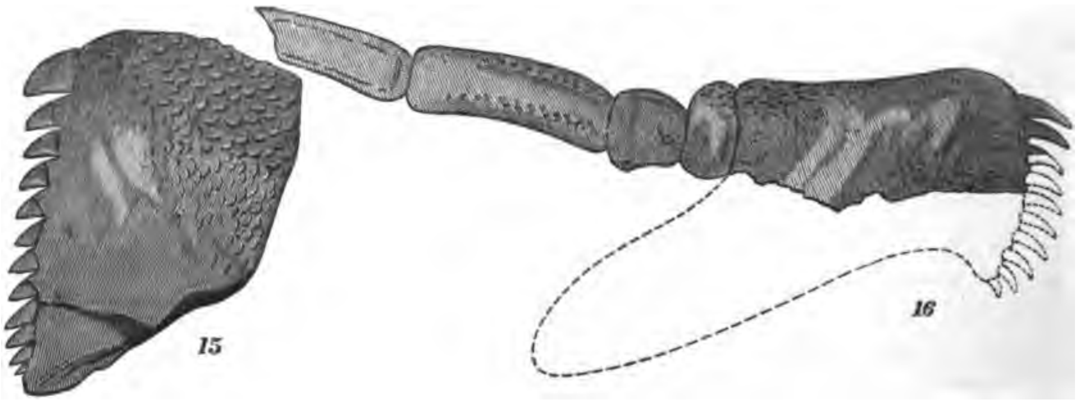

Fig. 15.—Mandibular border of ectognath of *Pterygotus ludensis,* Salter, from Mr. Lightbody's Cabinet.

,, 16.—An endognath of *Pt. ludensis,* with its palpus. Museum Pract. Geology. Both specimens from the Basement-beds of the Old Red Sandstone, Ludlow Railway, Ludlow.

Thoracic Appendages[1] (?) (Mem. Geol. Surv., Mon. I, pl. xii, figs. 4 and 5).—The nature of these is not understood, nor do these specimens show the characteristic irregular base. But they differ specifically both from the similar appendages referred to *P. problematicus* and *P. arcuatus*, by their deep terminal notch. The outer edges are thickened, and the substance of the whole appendage is thick. The lateral plicæ run down in oblique rows on the inner (?) surface becoming more and more linear, till they become straight lines, like the pennæ of a feather, and on the outer side; impressed distant converging striæ cut up, as it were, the whole surface into narrow bands, the termination of these bands being serrated projections in *P. problematicus*, but in this species they come to an even edge on the notched border.

Ovisacs (?).—The egg-packets (*Parka*), found in plenty with this species at Trimpley, show the membranous veil in several cases. The ova of considerable size, generally oval, and placed a little apart in the younger packets, but they become hexagonal or polygonal, from mutual pressure, in the older ones (see Pl. XVI, figs. 10 and 11).

Localities.—Base of the Old Red Sandstone, at Ludlow Railway Station (abundant); at Trimpley, north of Bewdley, associated with *Pteraspis Banksii.*

Species 7.—PTERYGOTUS GIGAS:—Salter. 1859.

PTERYGOTUS GIGAS, *Salter*. Mem. Geol. Surv., 1859, Mon. I, p. 83, pls. viii and ix.
— PROBLEMATICUS, *Banks*. Quart. Journ. Geol. Soc., vol. xii, 1856, p. 93, &c.

Although there are very strong grounds for considering the remains referred to this species to be only English representatives of the great Scotch *Pterygotus anglicus*, figured in Part I of this Monograph, we have not treated it here as synonymous because we have no new or more perfect materials to offer than those heretofore described in the 'Geological Survey Monograph.' Therefore, in deference to Mr. Salter's determination, we retain the species, giving his diagnosis, with only a few additional notes where needed.

For some years a large *Pterygotus* has been known in the beds of Downton Sandstone (Uppermost Ludlow Rock), worked for building purposes at Kington, Herefordshire, and a description of many of its parts was given by Mr. R. Banks, of Ridgbourne, in the 'Quarterly Journal of the Geological Society' for 1856. Since his description was written he has continued to labour assiduously to collect the fragments, and has been fortunate enough to discover nearly all the parts of this fine species. He has generously placed these fragile specimens in our hands, and presented a series of excellent drawings which were formerly exhibited at the Geological Society. In the paper quoted above the fragments were all considered to belong to the *P. problematicus* of Agassiz, a species for which there is unfortunately very scanty material, but which, as originally described, is a Ludlow Rock species identical with one of the Kington fossils, but not apparently with the principal and largest of them, here described, and which in many respects is very like *P. anglicus*.

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[1] I am at present quite unable to decide the true position of these fragments. (See Woodcut, Figs. 25—27, p. 91.)—H. W.

P. gigas has, in common with the latter species, the open scale-like sculpture on the body-rings, and the thick tubercular scales on their margin; the shape of the *epistome*[1] and head is very similar, but the latter is rounded, and not truncate in front.[2] The penultimate body-ring is wider and has a short keel on the upper surface only (while *P. anglicus* has one on both sides above and below),[3] and the tail-joint or telson appears to be emarginate instead of pointed. But if this character should be deceptive, there can be no doubt of the specific difference, since this joint is furnished with a most remarkable elevated crest or ridge, nearly half an inch high, which is quite absent in the Scotch species.[4]

As the fragments indicate a species of the largest size, the above specific name will not be inappropriate. The size of the chelate antennæ exceeds that of any known species.

There are two species in the Kington beds, *P. gigas* and *P. problematicus*, and it was, of course, possible that some of the parts assigned to the former might belong to the latter species. The subsequent discovery of nearly all the parts of *P. problematicus* shows that in this instance the fragments have been rightly collocated.

Head or *Carapace* (pl. viii, fig. 1, Mem. Geol. Surv., Mon. I).—Nearly semi-oval, convex, the width three inches and three quarters at the broad base, probably greater than the length. The specimen being imperfect behind, the true length is not known, but the portion preserved is three inches and a quarter long. The eyes are very large, three quarters of an inch long, oval, and prominent beyond the margin. They are placed very near the anterior end, and the space between them on the margin is about an inch and three quarters, while between the convex inner edges of the eyes it is about an inch and a half. The anterior border is arched and very slightly angular in front, with a crenulate edge. The sides are convex, their margin not visible. (See Woodcut, fig. 17, p. 81.)

In the centre of the carapace, and forming an equilateral triangle with the eyes, is an elongate tubercle. The general surface appears somewhat rugose (see Woodcut, fig. 17).

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[1] Thoracic plate, not epistome.—H. W.

[2] The head in *Pterygotus anglicus*, Ag., is now known to be rounded in front, not trapezoidal, as was believed to be the case in 1859, when the above description was penned (see *antè*, Part I, p. 36, Pls. I and II).—H. W.

[3] This appears to be an error. In *Pt. anglicus* the penultimate segment is only keeled upon the dorsal surface (see *antè*, Part I, p. 42, fig. 6, Pl. III, fig. 2, and Pl. VIII).—H. W.

[4] The Scotch species is proved to have a well-marked keel to the telson (see Part I, p. 42, Pl. II, fig. 1, and Pl. VI). In Pl. II, fig. 1, the young and perfect Pterygotus there drawn has a high ridge to the telson, which is clearly seen folded down towards the right side of the tail-plate. In Pl. VI it is erect and thickened into a strong keel by reason of the greater age of the individual.—H. W.

Thoracic Plate (formerly called the *Epistoma*, pl. viii, fig. 2, Mem. Geol. Surv., Mon. I).—The proportions of this plate and its sculpture are very like those of *P. anglicus*, and specimens figured indicate this part to be quite as large as in that species. The plicæ on the upper or front portion are crowded, and but slightly curved; those further back are semicircular or even semi-oval, while those near the apex of the side lobes are narrower and pointed as in the cognate species. Similar but smaller plicæ occur down the centre lobe, which does not appear to have prominent elongate scales, nor is it convex as it is in *P. anglicus*. Its base is broad and spear-shaped.

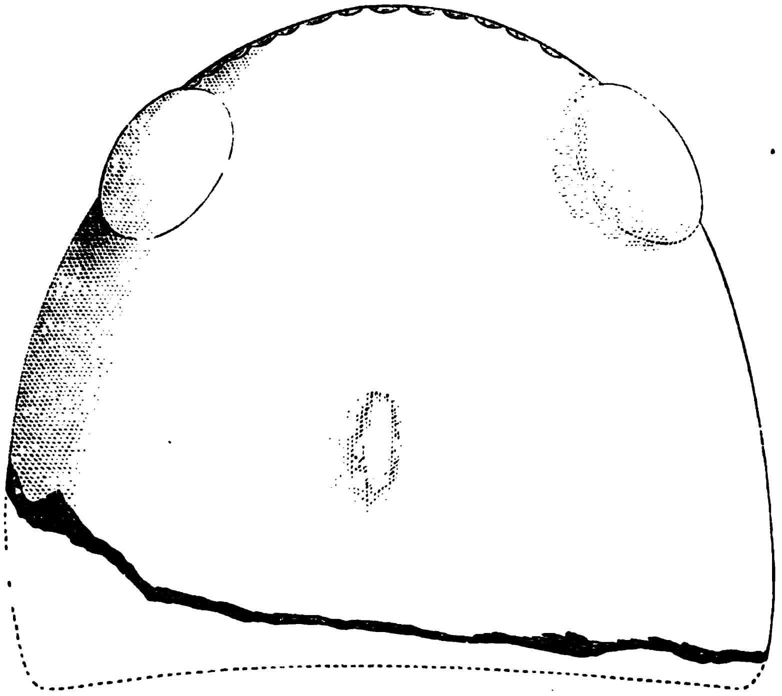

Fig. 17.—Head of *Pterygotus gigas*, Salter. From the Downton Sandstone of Kington, Herefordshire; in the Cabinet of R. Banks, Esq.

Body-rings.—The anterior body-rings (Mem. Geol. Surv., Mon. I, pl. viii, fig. 3), bear the squamæ only on their front half, and these are less curved and less crowded than in the corresponding segments of *P. anglicus*. The edge of the plicæ is thickened. Figs. 4 and 5 (op. cit.) must represent large segments from a portion of the body further back than fig. 3, for the squamæ cover the whole lower surface of the segment (fig. 5), and the greater part of the upper side (fig. 4). They are greatly more convex than in the Scotch species, the posterior ones especially being parabolic or even pointed in form, frequently three tenths of an inch long and equally broad. Fig. 5 (op. cit.) shows the closely squamate lateral edges of the segment, which are convex and rounded in the forward portion and sharply keeled behind. The front margin in both of these segments is contracted, for articulation with the previous joint, and has a broad groove running along its whole length. The hinder angles are a little produced.

Penultimate Segment (figs. 6 to 9, and pl. ix, fig. 15, Mem. Geol. Surv., Mon. I).—This joint is much wider than long, in the proportion of four inches and a half to two inches and a half; some specimens must have been fully five inches long, and, therefore, nine or ten broad. The segment is widest and flattest at the hinder end, the margins are compressed and keeled, except at the thickened and contracted base, and the angle (fig. 9) pointed and produced. The upper surface (fig. 7) is gently convex, but without any ridge, while the lower (?) (fig. 6) has a short thick keel extending half way up. It terminates on the hinder margin of the segment, which is rather deeply notched at this point. The surface is thickly covered with plicæ, both above and below, but they are much more prominent on the lower (keeled) surface[1] than on the other, where they are mere surface markings and often obliterated. They cover the whole of the segment, but are less thickly placed towards the hinder margin, at least on the under side (fig. 6). The margin itself is tubercular.

The squamate keeled lateral borders are ornamented with several (about four or five) rows of oblique thick plicæ, more prominent and larger on the lower side; these are continued from about the anterior fourth of the segment, where the keel commences, to the pointed hinder angle. Similar, but still larger, plicæ cover the central keel, and numerous shallow folds run obliquely backwards from the sides to the keel.

Telson or Tail-joint (pl. ix, figs. 16, 17, Mem. Geol. Surv., Mon. I).—The dimensions of this joint give the best indication of the size to which the species grew; its length was full 5 inches, and the width 4½. The largest specimens of this part in *P. anglicus* (pl. v, fig. 5, op. cit.) are rather longer, but narrower. The general shape was that of a broad and pretty regular oval, but truncated at the base and emarginate at the apex. The under side is flat, except at the origin of the joint, while it is somewhat convex; the median line is even concave. Oblique folds or lines, like those on the penultimate segment, occur on the forward half. The upper side is also flattened, but furnished along its whole length with a great central keel, rather thick at its origin, but becoming narrower and more elevated (six tenths of an inch high in the centre), and then decreasing towards the tip.

Sculpture as in the preceding segment. The blunt ridge of the central keel is covered with small squamate plates, and the margins have four or five rows of oblique elongate ones. The general surface is bare of plicæ, except near the base, where they are numerous and prominent both on the upper and under side.

Appendages.—Chelate Antennæ (pl. ix, figs. 1, 3, Mem. Geol. Surv., Mon. I).—Fragments only are yet found; the large base of the fixed claw is about five inches long to the first tooth (in the largest *P. anglicus* it is not more than three inches and a quarter), and one inch ten lines broad (nearly of equal breadth throughout). The articulating edge is long and oblique, the joint narrowing considerably into the serrate claw. Of this portion there is but little preserved, but it shows the chela to have had broad (probably subovate) cutting teeth, as well as numerous close-set smaller ones. These last are short, conical near the base of the fixed claw, and coarsely striated parallel to their sides, the striæ branching from above downwards. Further out (as shown in the specimen, fig. 2, op. cit., which may be the free claw), the smaller teeth are lanceolate and narrow, and the striæ parallel. These striæ are very closely set, much more so than in any other species. The teeth appear to have been irregular in size, and much crowded; a third specimen (fig. 3) shows three kinds, a small lanceolate one, larger subovate secondary ones, and one a great striate tooth, apparently the median one (see pl. vi, fig. 5, op. cit.), which is coarsely ribbed, and is, besides, serrated on the inner edge.

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[1] We have already stated, in a footnote, p. 80, that in *Pterygotus* there is no keel or ridge to the ventral surface of any segment of the body; Mr. Salter's description, given above, must therefore be reversed, and his fig. 7, pl. viii, op. cit., must be regarded as the *under* side of the penultimate segment, and fig. 6 as the *upper* or dorsal surface of the body.—H. W.

The *endognath* has somewhat broader and shorter teeth than that figured in pl. vii (op. cit.), and the second maxillary piece is more curved anteriorly. Both specimens are preserved in Mr. Banks' cabinet.

Of the palpi (pl. ix, figs. 5—7, Mem. Geol. Surv., Mon. I) only fragments are left. Fig. 5 shows four joints connected, but all compressed in a direction perpendicular to their length. Their diameter is half an inch, and their proportions may be compared with those shown in pl. vii, fig. 4 (op. cit.). The second joint is rather longer, and the third not quite so long as in *P. anglicus*. The other figured fragments are less distorted; fig. 6 shows the fourth joint fully one inch and a half long, with the tip expanded and bilobed. In fig. 7 one of the lobes bears a fringe of spines. All the joints show elongate squamæ on their outer side.

Swimming-foot (pl. ix, figs. 4—9, Mem. Geol. Surv., Mon. I). The great basal joint (fig. 8), with its serrated tip, closely resembles in form and sculpture that figured in pl. vii, 'Geol. Surv. Mon.,' the chief difference being the greater width of the foliaceous base, and the more backward position of the notch at the point of attachment for the succeeding joints. The serrate terminal lobe (figs. 4 and 9) has broad stout teeth, as usual, thirteen in number, slightly curved, the uppermost broader and shorter than the rest, the lowest a rounded lobe as broad as the two preceding teeth taken together. The teeth are shorter than in *P. anglicus*, especially the upper ones, so that the outline of the serrate edge is more curved. The perfect specimen is only three inches and a half long by two inches and three quarters broad, but fragments indicate a size equal to the largest specimens of the Scotch species.

Of the other joints of the swimming-foot only two or three specimens (pl ix, figs. 10—12, Mem. Geol. Surv., Mon. I) have occurred. Fig. 10 shows the upper surface of the right-hand swimming-foot, with two complete joints; the fourth and fifth, with a portion of the great penultimate joint. The latter joint is better shown in another fragment (fig. 10), which is in close juxtaposition, and has a fragment of the fifth joint attached to it.

The fourth and fifth joints closely resemble those in *P. anglicus* (see pl. vi, op. cit.), but the form of the penultimate or propodite is, as usual, characteristic. It is oblong, two inches and a half in length by one and a half broad, and is but little broader at one end than the other. The upper or proximal end is deeply bilobed, as in *P.* (now *Eurypterus*) *punctatus*, the lobes being apparently equally prominent, and the distal or outer end is trilobed; this is partly seen in fig. 10, but much better in fig. 11, where the outer lobe is pointed and prominent, the middle one rounded and shallow, and the inner truncate; the last forms nearly a straight line, ending in a sharp angle against the straight inner margin.

Both outer and inner margins of the penultimate joint are serrate, with elongate appressed squamæ, and the surface of the preceding joints (the fourth especially) has close and rather elongate plicæ.

Of the terminal palette there is no trace; its probable shape is given in the dotted outline (by Mr. Salter, in pl. ix, fig. 10, op. cit.).

Only the *metastoma* (pl. ix, fig. 13, Mem. Geol. Surv., Mon. I) remains to be described. It is greatly like that of *P. anglicus* (pl. vi, op. cit.), and chiefly differs in the more contracted base and large open plicæ of the surface. The notch is somewhat deeper. It may have been smooth over the hinder portion (as in pl. xii, fig. 3, op. cit.), which is the same or a closely allied species, and may be noticed here, though possibly it belongs to *P. ludensis*, above described. (See Woodcut below, Fig. 18.)

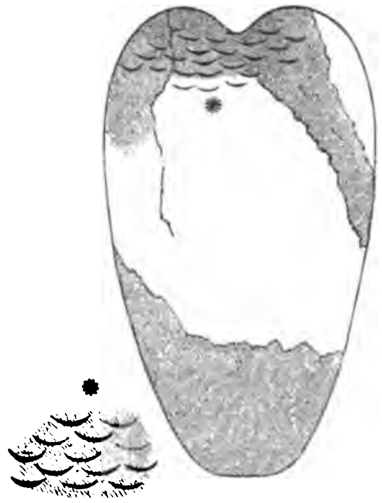

Fig. 18.—Metastoma, or post-oral plate, belonging either to *Pt. ludensis*, or to *Pt. gigas*, from the "Passage-beds" at Ludlow.

* A part of the sculpture magnified.

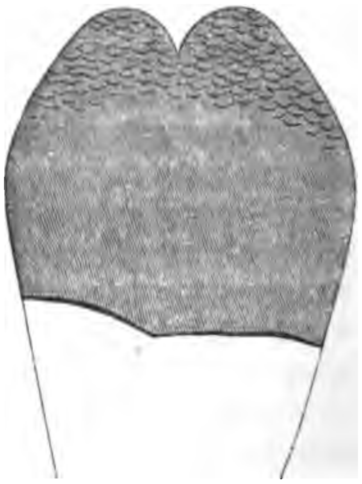

Fig. 19.—Imperfectly preserved Metastoma referred to *Pt. problematicus*, Upper Ludlow Rock, Ludlow.

This post-oral plate, in its anterior portion, a good deal resembles the fragment figured in pl. ix (op. cit.), the notch being a little less deep only. The shape is much more elongate than in *P. anglicus*, the length being as seven to four; the width is greatest at the anterior third, and the general shape ovate. The plicæ are large and open, and are confined to the anterior portion about the notch.

The basal joint of the swimming-foot (fig. 8), found at the same locality, is in almost every respect like that of *P. gigas*, having the teeth broad and short.

Locality.—Downton Sandstone (Uppermost Ludlow Rock) of Kington, Herefordshire. (Cabinet of Mr. R. Banks, of that place.) Some specimens, presented by that gentleman, are in the Museum of Pract. Geology; as are also specimens collected by Mr. A. Marston, of Ludlow. They were found at the Ludlow Railway Bridge, in the passage beds at the base of the Old Red Sandstone.

Species 8.—PTERYGOTUS PROBLEMATICUS:—Salter.

PTERYGOTUS PROBLEMATICUS, *Agassiz*. In Sil. Syst., 1839, p. 606, pl. iv, figs. 4 and 5 (and 6, tooth of *Sphagodus pristodontus*, Ag., tooth only).
—— —— *Strickland* and *Salter*. Quart. Journ. Geol. Soc., 1852, vol. viii, pl. xxi, figs. 1, 2, p. 386.
—— —— Siluria, 2nd edit., 1856, pl. xix, figs. 4—6.
—— —— „ 3rd ed., 1859, „ p. 265.
—— —— „ 4th ed., 1867, „ p. 237.
—— —— *Salter*. Mem. Geol. Surv., 1859, Mon. I, p. 89, pl. xii, figs. 7—16, 20, 21; and pl. xiv, figs. 16—18.

As this is the principal, if not the only, species in the true Upper Ludlow Rock which has the usual semicircular ornamental plicæ, it is to this that the name *problematicus* should be given; and fortunately, on one of the minute original fragments figured in the 'Silurian System,' the small intermediate plicæ are to be seen marking the species more definitely.

The large chela, figured as above under this name, by the late Mr. Strickland and myself, proves to be really an appendage of this same species, at least it is always associated with it in the same bed. Again, the antennary portions, fragments of body-rings, bases of the swimming-feet, post-oral plate, &c. (pl. xii, Mem. Geol. Surv., Mon. I), are all found in the Whitcliffe, Ludlow, or other localities of the Upper Ludlow Rock, and clearly differ from the corresponding parts in *P.* (now *Eurypterus*) *punctatus*, the only other large species occurring with them, as well as from those just described which are characteristic of the beds of passage above the top of the Ludlow series. *P. problematicus* may now, therefore, be considered an established species, and the cabinets of our Ludlow friends, Messrs. Cocking and Marston, have furnished many of the materials. It occurs, too, in plenty, as Mr. Lightbody's researches show, in the transition beds beneath the Old Red Sandstone (pl. xiv, op. cit.); and Mr. J. Harley, to whom we are indebted for much valuable help, has been fortunate enough to detect its fragments far up in the Cornstones of the Old Red itself, a higher limit than the genus had been known before to attain.

[If the large fragments from the transition beds above quoted, and figured on pl. xiv, Mem. Geol. Surv., Mon. I, be of the same species as the sculpture indicates, the body-segments attained a very large size, nearly three inches from back to front. As it is possible these may belong to a different species, I will describe these portions first.

Carapace (?) (pl. xiv, fig. 16, Mem. Geol. Surv., Mon. I).—A fragment, three inches by two and a half, has the surface sculptured, unlike the body-rings, *i. e.* much more finely marked, and without the regular increase in size and curve of the plicæ backwards. The anterior ones are nearly as much bent as the hinder ones, though smaller; all are but slightly prominent, and are covered by numerous smaller plicæ.

Body-rings (pl. xiv, fig. 17, op. cit.).—One of the broad abdominal rings, two inches and three quarters from back to front; the articulating front margin is rather deeply concave, and its edge is obscurely striated longitudinally. The plicæ are very numerous and close-set, not so large as in *P. anglicus*, or so straight on the forward edge, where, however, they are very closely packed. They are more open posteriorly, and cover more than half the segment, interspersed with very numerous minute semicircular plaits.

Another piece (fig. 14, op. cit.) is here considered as belonging to this species, but it only shows the interspersed plicæ over part of the surface, and it quite possibly belongs to *P. ludensis*, or even to a new species.

Penultimate Joint (pl. xiv, fig. 18, op. cit.) — Of this we have only the lower surface; and as the plicæ are restricted to the upper portions, and only a few small ones are interspersed, it is possibly not *P. problematicus*, but of the same species as the one (fig. 15) mentioned above. The width is greater than that of the same joint in *P. anglicus* or *P. ludensis*, being three inches and a half, while the length is only two and a quarter (or as fourteen to nine), which is about the proportion in *P. gigas*. The joint is not expanded posteriorly, as in that species, and the plicæ are semicircular, not pointed, on the lower side.]

In the true Ludlow Rock but few body-joints have been met with; the two best are figured from Mr. J. Harley's collection, viz. pl. xii, fig. 20, op. cit., must be one of the thoracic rings, and fig. 21 probably the tenth or last but two of the segments. Both show the minute interspersed plicæ very clearly, and these small plicæ extend over nearly all the segment, while the larger ones are confined to the anterior half.

Telson as yet unknown, as also is the thoracic plate.

Antennæ (pl. xii, figs. 7—10, Mem. Geol. Surv., Mon. I).—Fig. 10 is most probably part of the stem, and shows the large and small plicæ in perfection. Figs. 7 to 9 show the large characteristic chelæ, which can scarcely be confounded with those of any other species, the teeth being so much elongated. Fig. 7 is the fixed claw, with a widely expanded and largely dentate base. The shaft is parallel-sided (not tapering as in *P. ludensis*), and the teeth long-lanceolate, the large one being much longer than the diameter of the shaft (in fig. 7, fully three quarters of an inch long); the secondaries, three or four on each side of it, with small teeth interspersed, all linear-lanceolate, erect and remote, not crowded at their bases. In the fixed ramus they are either erect or (fig. 8) point forward a very little.

The striæ on the teeth are very fine and close; somewhat oblique on the great tooth, and more direct in the smaller ones. In *P. gigas* and *P. ludensis* they are coarser, and the teeth broad. The great terminal mucro is as broad and long as the primary tooth, or even longer, and is bent at right angles to the shaft.

Swimming-feet: Basal Joint (pl. xii, figs. 11—14, op. cit.). — Several fragments have been found of the great basal joint, and one tolerably perfect from the Whitcliffe, Ludlow (fig. 11). It shows a wide-expanded basal lobe, and the whole extent of the serrate tip, with the usual number of teeth (thirteen, or rather twelve in this specimen), in fig. 14 the upper tooth being obsolete. Fig. 13 *a*, from Ludlow, shows the full number.

The lobe in front of the teeth is arched and thickened in all the specimens (a character in which this species differs widely from *P. anglicus*), and the second tooth is more than twice the breadth of any of the others, conical, and but little curved; the remaining teeth are long, straight, narrow, and separated by about their width from each other in large specimens. These elongate teeth are very distinctive of the species. I believe I am not mistaken in referring Agassiz's figure of the *Sphagodus* tooth to this portion.

Metastoma (pl. xii, fig. 15, op. cit.) is cordate-ovate, narrower at the bilobed end, and has its greatest width below the middle, becoming angulated at that point. The notch is deep, the lobes rounded (the base is broken off); surface marked with open squamæ, but only near the upper end and about the notch. This post-oral plate is the broadest of any species known.

Fig. 16 is a plate of the same nature as those found with *P. ludensis*, and is possibly a thoracic or abdominal appendage, though, as no species are known with any such attached, its nature is quite doubtful. The entire form is better seen at p. 91 (Woodcut, Fig. 25), viz. a lobed broad emarginate plate (*d*), in the wide notch of which is attached the truncated sub-oval plate, *b*.

Localities.—Upper Ludlow Rock, Whitcliffe, and many places near Ludlow (Ludlow Museum and Museum of Practical Geology, Cabinets of Messrs. Lightbody, Cocking, J. Harley, and A. Marston). Kendal, Westmoreland (Museum of Practical Geology). Ludlow Bone-bed, Ludlow; Downton Sandstone of Bradnor Hill, Kington (Mr. R.

Banks's Cabinet). Base of Old Red Sandstone, Ludlow Railway Station (Museum of Practical Geology). Cornstones of Hopton Gate (Cabinet of Mr. J. Harley).

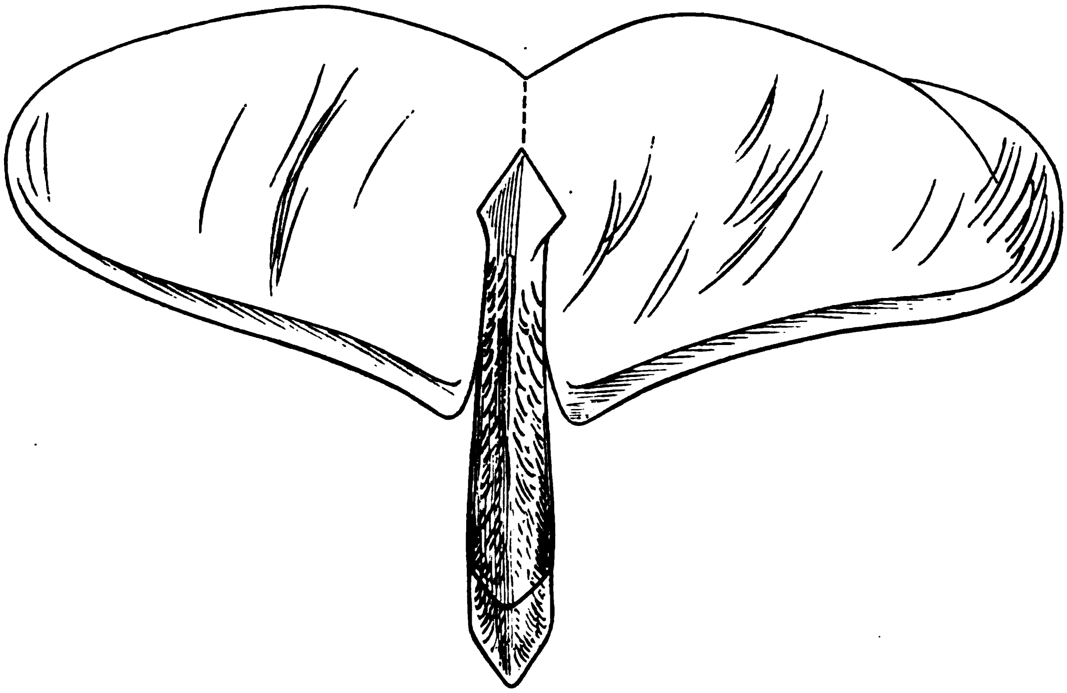

FIG. 20.—Thoracic plate, copied from an unpublished sketch by Mr. J. W. Salter, and referred by him to *Pterygotus problematicus*, Ag. Locality of specimen unknown.

One of the most widely spread species; it is probably this which occurs in the Upper Llandovery Rock or "May Hill Sandstone" of the Obelisk, Eastnor Park.

Several fragments, probably belonging to this species, have been obtained from the Wenlock Shale and Limestone (together with other remains referable to *Eurypterus punctatus*), from Dudley and Malvern, and are preserved in the British Museum, and in the Cabinet of John Gray, Esq., of Hagley, and in those of Messrs. Henry Johnson, E. Hollier, and C. Ketley, of Dudley.

Species 9.—PTERYGOTUS ARCUATUS:—Salter. 1859.

PTERYGOTUS ARCUATUS, *Salter*. Mem. Geol. Surv., 1859, Mon. I, p. 95, pl. xiii, figs. 8, 12, 13, 15, and 16.

This name is applied to a large and fine species, of which several fragments occur in the Lower Ludlow Rock of Leintwardine, with the more common *P.* (now *Eurypterus*) *punctatus*. It is clearly distinct from that species; but, except for the total absence of any minute interspersed plicæ, the body-segments might be easily mistaken for those of

P. problematicus, to which it is closely allied; and with it, in the same beds of Lower Ludlow Rock, occur antennæ, the obscure appendages (figured in our Woodcut, Fig. 25, p. 91), swimming-feet, maxillæ, and other oral apparatus, differing specifically from those of *P. problematicus*, and yet more distinctly separated from the portions of *P.* (now *Eurypterus*) *punctatus* found in the same beds. Of these fragments the body-segment must receive the name, the other pieces being only provisionally arranged with it. They all resemble the corresponding parts in the Upper Ludlow species.

Body-segments (pl. xiii, fig. 12, Mem. Geol. Surv., Mon. I).—This specimen is clearly, from its shape, the second body-segment, seven inches broad and more than one inch and a half deep. It is curved, and more oblique laterally than in *P. anglicus*, the sides forming an angle of 65° with the base. The anterior edge is much more sinuated than the posterior, owing to the deep excavation to receive the first segment; but the central part is strongly arched forward on both margins. The lateral anterior process is broken off, but enough remains to show it was prominent. The sides are oblique, inclined forward at an angle of 80° from the posterior angle, which is rounded off. The margin is crenulated, the prominent minute sculpture confined to the anterior third, but continued more faintly over a large part of the rest of the segment.

A specimen, crushed longitudinally, shows that the species was rotund in section, as in *P.* (now *Eurypterus*) *punctatus* and others.

Antennæ.—In all probability, pl. xiii, fig. 8, Mem. Geol. Surv., Mon. I, represents the antenna of this species. Its resemblance to those of *P. problematicus* is very close. The shaft is linear, the long end turned abruptly up, and the teeth straight, narrow, and remote, as in that species; but the chela is much more slender, three inches and a half to four inches long, and the larger central tooth is scarcely longer than the diameter of the shaft itself, while the secondary teeth, some of them at least, approach it more nearly in size. The tooth at the base of the large terminal mucro is appressed against it, and the mucro itself (pl. xi, fig. 3, op. cit.) is sometimes oblique. All the teeth are finely striate, the striæ tending obliquely backward on the principal teeth. There are numerous sharp, conical, minute teeth between the secondaries.

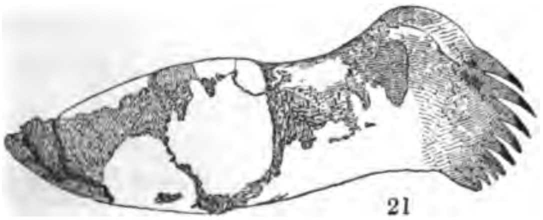

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Fig. 21.—The basal joint of an endognath of *Pt. arcuatus*, Salter.

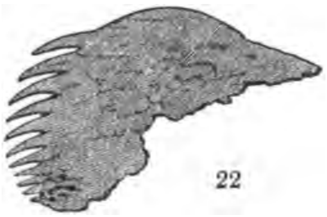

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Fig. 22.—Mandibular border of one of the endognaths of *Pt. arcuatus?*

Both specimens from the Lower Ludlow Rock, Leintwardine, Shropshire.

Endognaths.—Most probably, pl. xiii, fig. 15, Mem. Geol. Surv., Mon. I, represents the first or second pair of these organs; and it is pretty clearly referable to *P. arcuatus*, and not to *P.* (now *Eurypterus*) *punctatus*, which has much shorter and blunter mandibles (pl. xi, fig. 6, op. cit.). It is elongate, or even falcate, the upper lobe greatly convex, the posterior portion drawn out laterally instead of backwards; the surface closely sculptured all over. The teeth are not oblique, straight, and conical, as in *P.* (now *Eurypterus*) *punctatus*, but lanceolate and curved, and directed outwards. About ten or eleven are free, the rest confused, either in a horny plate or mixed with setæ. In this particular and in the production of the lower lobe it resembles *P.* (now *Eurypterus*) *punctatus*, but the great curvature and elongation of the plate distinguish it.

Base of Swimming-foot (pl. xi, fig. 10, Mem. Geol. Surv., Mon. I).—Most probably, from the very convex form of the anterior edge, and the greatly elongate teeth, this belongs rather to the present species than to *P.* (now *Eurypterus*) *punctatus.*

Post-oral Plate (pl. xv, fig. 5, Mem. Geol. Surv., Mon. I).—Found at Leintwardine by Mr. Alfred Marston. It differs from the corresponding plate in all the species; having the lobes of the apex narrow, and nearly their own width apart, the sinus between them being very wide and shallow, instead of a simple deep notch. The plate is cordato-lanceolate; for the upper two thirds it is oval, the greatest width being rather below the upper third; the base is rather suddenly contracted, and tongue-shaped.

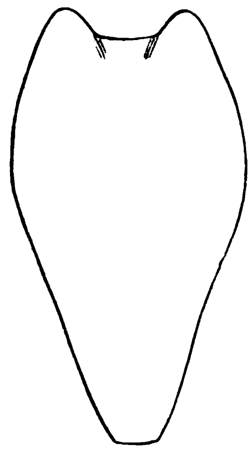


FIG. 23.—Post-oral plate, or metastoma, of *P. arcuatus*, Salt. (Natural size.)

Thoracic (?) *Appendage* (pl. xiii, fig. 16, Mem. Geol. Surv., Mon. I).—This is more perfect than any other specimen, though only the impression of one side. The large ovate terminal plate (*b*) shows well the gradation between the ordinary plicæ and the long lateral plaits; the middle line is bare of any ornament. At the apex are seen two or three of those impressed lines which are so much more conspicuous on the opposite surface, and which seem to divide the plate into laciniæ (*a*). The plate is indented at its basal end, corresponding to the central depression (ridge in the cast) of the preceding joint. This joint is very irregular in shape, the lobes on one side being single, on the opposed side double. Both are marked with minute plicæ near the edges. (See Woodcuts, page 91, Figs. 25—27.)

Locality.—The above-mentioned fragments have all successively come to light during the active researches of the Ludlow geologists in the quarries of Lower Ludlow Rock at Leintwardine, particularly in one at Church Hill. There are many new Crustacea to be described from the same quarry.

Species 10.—PTERYGOTUS (?) STYLOPS:—Salter. 1859.

Pterygotus stylops, *Salter.* **Mem. Geol. Survey. Mon. I, 1859, p. 55, pl. xii, fig. 47. (Reproduced in our Woodcut, Fig. 24.)**

This remarkable small carapace has occurred to the assiduous search of Mr. R. Banks, of Kington.

Only the anterior part is preserved, and even of this the frontal portion between the eyes is broken off; it was, perhaps, less prominent than the dotted line indicates. The forward position and round form of the great eyes very much assimilate the species to *Sl. acuminata;* but without doubt it belongs to the true *Pterygotus* (near, perhaps, to *Pt. raniceps,* from Lanarkshire, see p. 71).

The eyes are remarkably prominent and turgid, a slightly raised fold of the carapace encircling them. A small tubercle, like that on the same part in *Pterygotus gigas,* occurs on the median line of the head, and rather nearer to each eye than their distance from one another (probably indicating the position of the ocelli). As only a single broken specimen has occurred, it is useless to describe it further. There can be no doubt of the distinctness of the species.

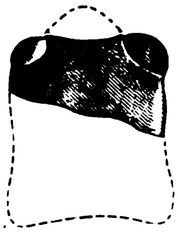
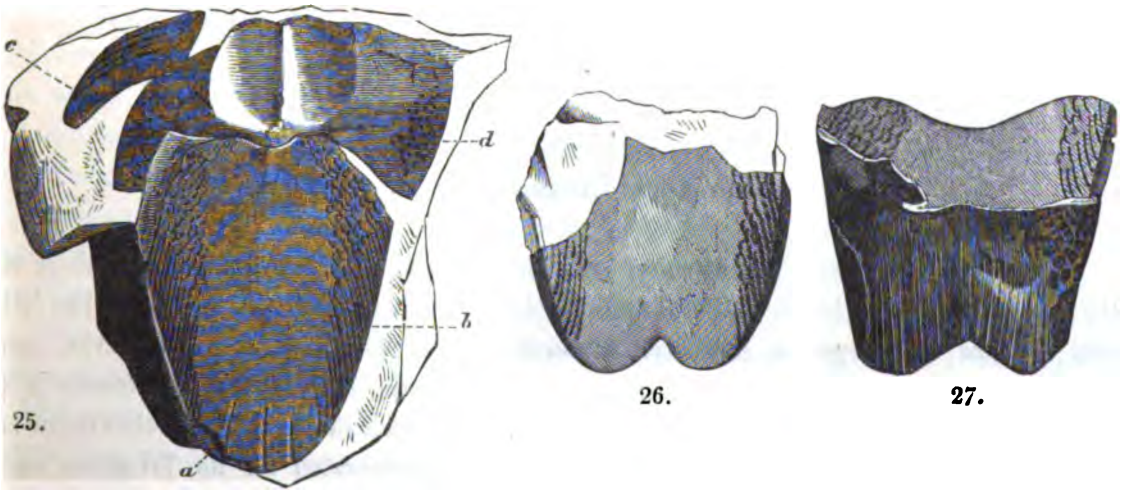


Fig. 24.—Head of *Pterygotus stylops,* Salter.

Locality.—Kington, Herefordshire. Collection of Mr. R. Banks, of Kington.



25. 26. 27.

Figs. 25—27. Crustacean appendages, doubtfully referred by Mr. J. W. Salter to *Pterygotus problematicus, Pt. arcuatus, Pt. ludensis,* or to one of the species common to the Ludlow Rocks. The ornamentation, when preserved, resembles that peculiar to *Pterygotus.* Lower Ludlow Rock, Leintwardine.

NOTES ON SILURIAN LOCALITIES IN THE WEST OF ENGLAND WHERE FOSSIL CRUSTACEA BELONGING TO THE ORDER MEROSTOMATA HAVE BEEN DISCOVERED.

BY THE REV. W. S. SYMONDS, M.A., F.G.S., OF PENDOCK.

(Written to accompany Mr. HENRY WOODWARD's 'Monograph on British Fossil Crustacea.')

1.—*Pterygotus* OF THE UPPER LLANDOVERY SANDSTONE.

Having been requested by my friend Mr. Henry Woodward, of the British Museum, to give a short description of the principal localities in which those remarkable Crustacea, the *Pterygoti*, *Stylonuri*, and *Eurypteri*, are found in the region of Siluria, I cannot do better than allude, in the first place, to the oldest known form of *Pterygotus*, discovered some years ago by Mr. John Burrow, of Great Malvern, and figured in the 'Memoirs of Hugh Edwin Strickland,' by Sir Wm. Jardine, Bart., under the title of "*Pterygotus problematicus.*" It is the jaw-foot only that is preserved. The strata in which the relic was discovered belong to the upper series of the Upper Llandovery beds, where they support the Obelisk in Eastnor Park, near Ledbury, Herefordshire. The common fossils of these strata are the *Nucula Eastnori*, with *Pentameri* and *Stricklandiniæ*. The author of these notes was present with the Malvern Field Club when this oldest known evidence of the existence of *Pterygotus* was discovered.

2.—WENLOCK LIMESTONE AND SHALE.

Although I am tolerably conversant with the *fossils* as well as the physical geology of the Wenlock rock series, it was not until lately that I became acquainted with the fact that remains of *Pterygotus* had been found therein. Mr. Woodward, however, has directed my attention to the occurrence of portions of the body of this Crustacean in a slab of Dudley Limestone in the British Museum. The rock in which these relics occur is undoubtedly the well-known Wenlock Limestone, so celebrated for its Trilobites and Crinoids. The remains occur not only imprinted upon shale attached to the limestone, but, in several instances, in the limestone itself.

The first of these remains, consisting of small fragments only, covered with the characteristic scale-markings, were obtained by Mr. John Gray, of Hagley, and are now in the British Museum.

In the National Collection are also a jaw-foot and several united body-segments of *Pterygotus*,[1] obtained by Mr. Charles Ketley, of Smethwick. Other remains of the same genus are, Mr. Woodward informs me, to be seen in the cabinets of Mr. E. Hollier and Mr. Henry Johnson, of Dudley.

Some of these specimens may be referable to *Pterygotus problematicus*, giving to this species a very wide range in time, as we find its remains in the Upper Llandovery Sandstone, the Wenlock series, the Ludlow rock, and possibly in the Passage-beds.

3.—AYMESTRY ROCK.

The next oldest rock bearing evidence of the existence of *Pterygotus*, that I am aware of, is indicated by the discovery of a "jaw-foot" of *Pterygotus* by myself in the Aymestry rock of Gorstley, near Newent, many years ago. This specimen was forwarded to Sir Roderick Murchison, and is now in the Museum at the College, Great Malvern. This rock is quarried to some extent at Gorstley, and is somewhat remarkable for containing nests of beautiful spicules of the sulphuret of nickel. I have seen the internal casts of *Rhynchonella Wilsoni* filled with these spicules.

4.—LOWER LUDLOW ROCKS.

The next stratified rocks in which we find remains of *Pterygotus*, and also of *Eurypterus*, are the Lower Ludlow beds of Church Hill, Leintwardine. They are shaly beds, which occupy the uppermost strata of this formation, and have furnished the beautiful series of fossil Star-fishes and Crustaceans found by Mr. Lightbody, Mr. Marston, and other geologists. In these strata also was discovered the *Scaphaspis ludensis*, by Mr. John Edward Lee, of Caerleon. This Fish is at present the oldest known form of vertebrate life. We have visited this quarry in company with Mr. Lightbody and Mr. Marston more than once. The section is now nearly destroyed, as the quarry is almost filled up. The remains of *Pterygoti* have been found all through the beds; and in 1865 a new species of *Eurypterus* from them was described by Mr. Henry Woodward.

We were conducted by Mr. Marston to a quarry in a lane called "The Old Road," near to Leintwardine, where the shale is found between masses of the *Pentamerus Knightii* limestone, and where also *Pterygoti* have been found. This *Pentamerus Knightii* limestone is more or less associated at Leintwardine with the uppermost layers of the Lower Ludlow Rock, and is not altogether on the same horizon as the so-called "Aymestry" or

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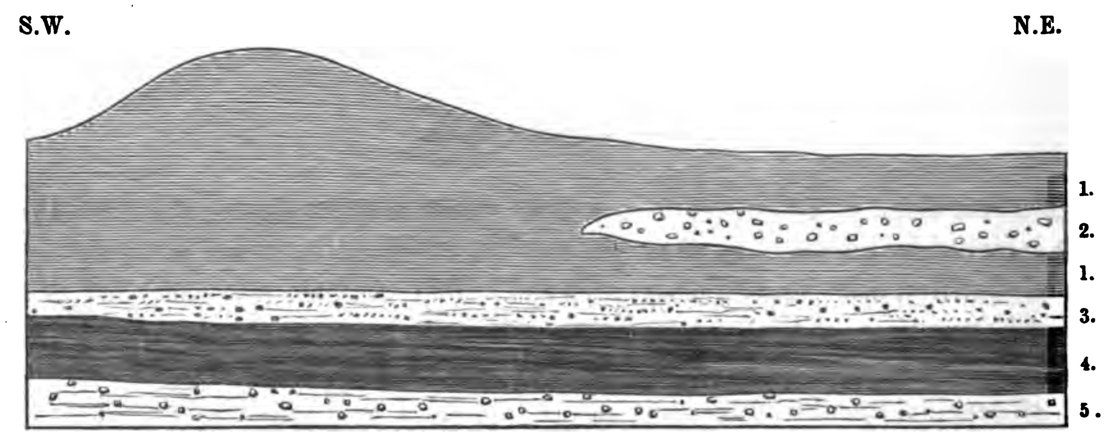
[1] The ornamentation upon these and other portions resembles that figured and described by Mr. Salter as *Pterygotus* (now *Eurypterus*) *punctatus*.—H. W.

Upper Ludlow Limestone of Ledbury and Woolhope. I agree with Mr. Lightbody and Mr. Marston that it should not be considered as a distinct formation, as it is intercalated at different horizons in the Ludlow rocks, both upper and lower.

FIG. 28.—SECTION OF OLD ROAD QUARRY (FROM A SKETCH BY MR. MARSTON) AT CHURCH HILL, LEINTWARDINE, SHROPSHIRE.



1. Shale like Lower Ludlow Shale.
2. Intercalated mass of nodular limestone, with *Pentamerus*.
3. *Pentamerus* bed, about 18 inches in thickness.
4. Shaly bed (about 3 feet thick), with Star-fishes, *Pterygotus*, and *Eurypterus*.
5. Thick bed, with *Pentamerus Knightii*.

5.—UPPER LUDLOW ROCK.

The name of "Seraphim" was given to certain winged-looking bodies (*Pterygotus*, Agassiz) by the Scotch quarrymen who first found them in the Lower Old Red Sandstone of Scotland. In pl. iv, figs. 4, 5, of Murchison's 'Silurian System,' a fragment of the carapace of *Pterygotus* is figured by Agassiz, and he then came to the conclusion that the animal it belonged to must be referred to the class of Fishes, while Hugh Miller, in his 8th chapter of the 'Old Red Sandstone,' gives a graphic account of the after-judgment of Agassiz, and how, in the presence of himself, Sir R. Murchison, and others, "his eye brightened," as he looked upon better specimens of "the huge Crustacean of Balruddery," and he said, turning to the company, "I will tell you what these are,—the remains of a huge lobster!"

It was of the merest fragments of this "Seraphim" from the Upper Ludlow rocks, in the collections of the Rev. T. T. Lewis and Dr. Lloyd, that Agassiz declares, in the 'Silurian System' (chap. xlv, p. 606), these remains belong undoubtedly to the same animal as the "Seraphim" of the Old Red Sandstone of Scotland.

Mr. Hugh Strickland read a paper[1] before the Geological Society in June, 1852, on the occurrence at Hagley, four miles north-east of Hereford, of the Ludlow Bone-bed, "a stratum interesting, not only for its wide extension, as contrasted with its very slight vertical thickness, but also as presenting nearly, if not quite, the earliest known indication of vertebrate life on the surface of our planet."[2] The writer of these notes accompanied Mr. Strickland and Mr. Scobie on the original discovery of this protruded mass of Upper Ludlow rock, which is in close proximity to a trap-dyke at Bartestree, there seen to traverse and alter the Lower Old Red Sandstone. The following is the section, taken from our measurements made on the spot:

	Feet.	Inches.
Old Red Sandstone.—Red clays and marls . . .	12	0
Brownish beds	2	0
Flaggy beds, micaceous	2	0
Downton Beds.—Yellowish sandstones, with carbonized Plants .	2	0
Clay	0	6
Micaceous yellow beds, with Plants	4	0
Bone-bed, with teeth and spines of Fish, and *Pterygotus* . .	0	1
Upper Ludlow Beds.—Numerous fossils and *Pterygotus* claw, in the Strickland Collection at Jardine Hall . . .	4	0

The chelæ of a *Pterygotus* were afterwards discovered by Mr. Scobie in the Upper Ludlow rock at Hagley, and forwarded by him to London, where it was examined by Mr. Salter, and described by him[3] as being especially interesting, and exhibiting the limbs of a Silurian fossil not hitherto discovered. These he connected satisfactorily with the species so fully figured by Agassiz, which was obtained from the basement beds of the Old Red Sandstone of Forfarshire.

On the same slab with it are specimens of *Orthis lunata* and *Orbicula rugata*, fossils of the Upper Ludlow Rock, and not found in the higher, yellow, Downton Sandstones. This *Pterygotus* claw is in the cabinet of Mrs. Hugh Strickland, at Jardine Hall, Dumfriesshire, and is figured, 'Quart. Journ. Geol. Soc.,' vol. viii, pl. xxi, under the name of *Pterygotus problematicus*. The pit at Hagley, though still open, has not been worked for some years; but I well remember having seen fragments of the carapace of *Pterygotus* in the yellow Downton Sandstones which overlie the "Bone-bed." The "Bone-bed," too, of Hagley Quarry is especially rich in Crustacean and Ichthyic remains.

The line of junction between the Passage-rocks of the Old Red Sandstone with the Upper Ludlow rocks strikes in a north-east direction from the Painscastle Hills to Kington, and thence flanks the hills which run by Shobdon and Richards Castle to Ludlow. The Upper Ludlow rock is seen well filled with fossils along Hergest Ridge, and thence by Gladestry to Painscastle, where it is overlain by ridges of the lowest Old Red Sandstone.

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[1] 'Quart. Journ. Geol. Soc.,' vol. viii, p. 381.

[2] Op. cit., vol. ix, p. 8. [3] Op. cit., vol. viii, p. 386.

These strata furnish occasionally the remains of the carapace of *Pterygotus*, which I have myself seen there in the same slabs with *Platyschisma helicites*, and the characteristic *Chonetes lata*.

At Bradnor Hill, near Kington, the lane which leads to the hill from Newton exposes what I consider to be the summit of the Upper Ludlow rock, and the Bone-bed associated with its upper layers. These beds contain true Upper Ludlow fossils, as *Cornulites serpularius*, *Platyschisma helicites*, *Chonetes lata*, *Rhynchonella nucula*, *Orbicula rugata*, and *Orthoceratites* of two or three species, and which are not found in the overlying Passage-beds proper. Remains of *Pterygotus* also occur in these strata.

6.—PASSAGE-BEDS.

The transition- or "Passage-beds" between two great formations often furnish a series of fossils of the highest value to the palæontologist, and the Passage-rocks between the Upper Silurians and the Lower Old Red Sandstone are no exception to this rule. The occurrence of large Crustacea other than *Trilobites* in the older rocks was hardly known until about the year 1855, when discoveries were made in Scotland and Siluria of several new forms of fine Crustacea, which have been described by Salter, Huxley, and more lately by Woodward. In many localities these remains of Crustaceans are accompanied by the relics of Fishes, such as *Pteraspis* (the oldest form of which has been found in the Lower Ludlow beds, below the Aymestry Limestone), *Cephalaspis*, *Auchenaspis*, and *Onchus*, two of which forms, *Pteraspis* and *Onchus*, range from Silurian deposits into the Middle Old Red, for remains of both these genera have been detected in rocks above the "Cornstones." As, however, the characteristic Silurian shells do not appear in any quantity above the "Bone-bed," for convenience sake I place the base of the "Passage-beds" at the "Bone-bed," inclusive. I include in the "Passage-beds" all the strata from the summit of the Upper Ludlow Rock proper to the micaceous flags and red marls which herald in the Old Red proper, and which contain traces of *Cephalaspis Lyellii* and *Scaphaspis Lloydii*, two Fishes abundant in the overlying Cornstones.

It was in 1854 or the commencement of 1855 that my friend Mr. Richard Banks, of Ridgebourne, Kington, first directed my attention to the remarkable collection of fossils he had obtained from several localities in that neighbourhood. I acquainted Sir R. Murchison with the fact of their discovery, and papers were subsequently published in the Journal of the Geological Society and in the 'Edin. New Phil. Jour.,' by Mr. Banks, Sir P. Egerton, Sir R. Murchison, Mr. Salter, and myself, with descriptions of the fossils and their position in the strata in which they were discovered. (See 'Edin. New Phil. Jour.,' April, 1855, and Oct., 1856. Also 'Quart. Journ. Geol. Soc.,' May, 1856; and March 25, 1857, &c.)

In addition to the discovery of some new forms of Fish, Mr. Banks found the relics of several Crustaceans, such as *Pterygotus* and *Eurypterus*; but on visiting the localities in which the fossils were found on several occasions, I am satisfied that the sites from which they were obtained are all *below* the Upper Ludlow Rock in stratigraphical position.

In strata that are intermediate between the Upper Ludlow Rock and the Yellow Downton Sandstone, Mr. Banks found *Pterygotus* remains associated with *Platyschisma helicites* and a small *Lingula*; this was between Newton and Bradnor Hill. The overlying strata also contain remains of *Pterygotus* with the *Lingula cornea* of the Downton Sandstones.

At Ivy Chimney is a sandstone quarry low down on Bradnor Hill, which furnished to Dr. Melville, Mr. Lightbody, and myself on one occasion the head of *Eurypterus*. These beds are apparently lower in position than the Downton Sandstone. The Downton Sandstone on Bradnor yields throughout remains of *Pterygotus*, *Eurypterus*, and *Cyathaspis Banksii*, with *Lingula cornea*. Again, these crustacean remains are found in a quarry at the Lodge Farm, Huntington. New Radnor church is built of Downton Sandstone, from a quarry between New Radnor and Harley, in an interesting outlier of Downton Rock; crustacean remains, with *Lingulæ*, occur in the *débris* which is strewn around.

7.—PASSAGE-BEDS AT LUDLOW.

The lowest of the Passage-beds in the section on the Shrewsbury and Hereford Railway, near the Ludlow Tunnel, are beds which are believed to be the equivalents of the Upper Downton Sandstone. The same history attaches to the "Tin Mill Beds," near Downton. *Pterygotus gigas*, *Pterygotus Banksii*, and *Lingula cornea*, with *Eurypterus linearis*, have been found in these strata. The lower Bone-bed occurs on the right bank of the Teme, near Ludlow; but, owing to a fault or overlap, I believe it has not been found on the left bank near the Ludlow Tunnel. Indeed the Ludlow section will not bear comparison with the Ledbury section (to which we shall allude bye and bye) as regards the perfect continuity of rock-succession. The different beds are much obscured, and their relation to each other was difficult to determine. There is a grey sandstone between Onibury and Norton, and at the Tin Mills near Downton, which I believe to be the equivalent of certain grey grits at Ledbury, and this contains *Cephalaspis Murchisonii* and a *Lingula* at both places, with many carbonaceous remains of Plants.

The Olive Shales described by Mr. Marston ('Geol. Mag.,' 1870, vol. vii, p. 408) overlie these grey micaceous sandstones.

The Olive Shales were excavated on the line of the Shrewsbury and Hereford Railway; and when I visited this locality in company with my friends, Messrs. Lightbody, Salwey, and Marston, they were yielding a rich harvest of organic remains. Mr. Lightbody's cabinet and the Museum at Ludlow are both enriched with rare fossils from these shales. In the middle of these beds was a deposit, termed by my friends an "upper bone-bed,"

Localities.		*Formations.*	*Fossil Contents.*
Near Ludlow, at Boulden, Whitbaitch, and Oakley Park.	Old Red Sandstone.	Lower Cornstones.	*Pteraspis, Scaphaspis, Cephalaspis Lyellii, Zenaspis Salweyi.*
		Micaceous soft red marl beds.	*Pteraspis, Scaphaspis,* and *Cephalaspis.*
		Hard stone.	
Paper Mills.	Passage-beds.	Hard micaceous beds.	
		Olive Shales.	*Cephalaspis Murchisonii, Pterygotus Banksii, Eurypterus* (3 species).
Overbury Ludlow Railway.		Hard micaceous beds.	
		Different coloured thin beds.	*Auchenaspis, Scaphaspis.*
		Red beds.	
Bull Ring, Ludlow.	Upper Silurian.	Greenish-grey micaceous beds with nodules of soft perishable mudstone.	
Onibury, &c.		Downton Sandstone.	*Pterygotus* (scarce). *Eurypterus.* *Pterygotus, Eurypterus.*
Forge Bridge.		Dark-olive stone.	
		Shales.	
		Upper Ludlow beds.[1]	Bone-bed.

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[1] From a section by Mr. Marston, with the exception of placing the demarcation of the Upper Ludlow at the Lower Bone-bed.

which yielded to their hammers no less than three species of fossil Fishes, *Cephalaspis Murchisonii, C. ornatus*, and *Auchenaspis Egertoni*, which Sir P. Egerton informs me is a different species of *Auchenaspis* to that found at the Ledbury section outside the Tunnel. At the Tin Mills, in this olive shale, no less than three species of *Eurypterus* were found, together with the *Pterygotus Banksii* of the Kington beds.

Purple grits full of mica succeed these shales at the Tin Mills, and they contain a large *Lingula*.

Over these again rests a grey micaceous sandstone, with *Lingulæ* and carbonaceous markings. These strata are upon nearly the same horizon as the grey *Auchenaspis* grits of Ledbury.

8.—Passage-beds at Ledbury, Herefordshire.

In my paper on these rocks as displayed on the line of railway between Malvern and Ledbury, in and outside the Ledbury tunnel, the following passage occurs:[1]—"In my communication on 'The Old Red Sandstone of Herefordshire,' published in the 'Edinburgh New Phil. Journ.' (April 1, 1859, p. 232), I expressed my opinion that the Ludlow sections on the horizon of the Passage-beds above the Downton Sandstone are broken by faults, and that the true succession is therefore destroyed. I had come to this determination long before the beds now developed in the railroad-cutting at Ledbury were exposed to view; and, having again visited Ludlow, and compared the Passage-rocks of that district with those of Ledbury, I am convinced that nowhere perhaps in the world is there such an exhibition of Passage-beds presented to the eye of the geologist as at the Ledbury Tunnel on the Worcester and Hereford Railway."

I have visited Ludlow on more than one occasion since writing these words, and as I have no reason for altering my opinion, I do not hesitate to reproduce the Ledbury section, marking more especially the beds in which the remains of Crustaceans occurred. It will be sufficient to say here that the section was entire throughout, not being interfered with by any break or obscurity, and was carefully measured off yard by yard and inch by inch. The Aymestry rock, with *Pentamerus Knightii*, was cut through in the Tunnel, and was apparently higher in the Ludlow series than the *Pentamerus Knightii* rock of Leintwardine. Thus we had—1. Aymestry rock (ten feet); 2. Upper Ludlow beds with *Chonetes lata*, &c. (140 feet; Ludlow Bone-bed not detected); 3. Downton sandstone (nine feet), with *Lingulæ* and fragments of carapace of *Pterygotus*; 4. Red and mottled marls and thin sandstones (210 feet), with *Lingulæ* and remains of *Pteraspis*; 5. Grey shales and grits at the tunnel's mouth (eight feet), with *Pterygotus* and *Cephalaspis Murchisonii*; 6. Purple shales and thin sandy beds (thirty-four feet), with a few remains of *Lingulæ*; 7. Grey marl, passing into red and grey marl and bluish-grey rocks (*Auche-*

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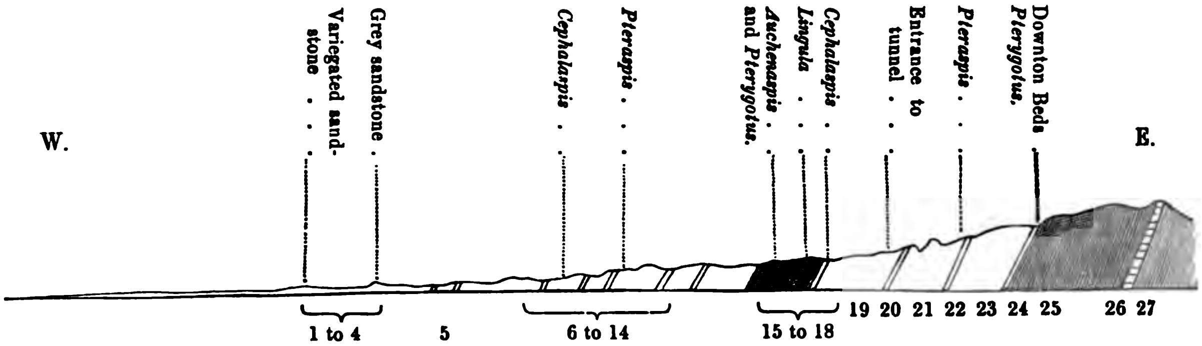
[1] 'Quart. Journ. Geol. Soc.,' vol. xvi, p. 193.

naspis grits, twenty feet), with *Auchenaspis Salteri*, *Pterygotus*, *Cephalaspis* (two species), and *Lingulæ*. These strata pass conformably into red marly beds with white and reddish sandstones which yielded fragments of *Pterygotus*, also remains of a *Pteraspis* now in Lord Enniskillen's collection, and a *Cephalaspis*.

FIG. 29.—SECTION AT THE RAILWAY TUNNEL, NEAR LEDBURY, HEREFORDSHIRE.[1]



Explanation of Section.

1. Marl with some bands of sandstone.
2. Grey rock.
3. Marl.
4. Grey rock.
5. Marl.
6. Grey rock.
7. Marly rock with *Cephalaspis*.
8. Grey rock.
9. Marly rock.
10. Grey rock.
11. Marly rock with *Pteraspis*, some of the hard bands finely laminated.
12. Grey rock.
13. Marl.
14. Grey rock.
15. Marl.
16. Grey marl and Grey rock.
    - Red and blue marls.
    - Yellowish-grey sandstone, 18 inches.
    - Greenish shale, 6 inches.
    - Dark grey sandstone, 8 inches.
    - Deep red micaceous shale.
17. Purple sandstone.
18. Purple marls and shales.
19. Grey shale.
20. Red marl.
21. Red sandstone.
22. Red marl with *Pteraspis*.
23. Mottled marls.
24. Red marls with grey spots.
25. Downton sandstone with red, grey, and yellow marls.
26. Upper Ludlow rocks, about 140 feet.
27. Aymestry rocks, about 10 feet thick.

9.—THE PASSAGE-BEDS OF THE WOOLHOPE DISTRICT.

These strata have been well described quite recently by my friend the Rev. P. B. Brodie, in the 'Quart. Journ. Geol. Soc.,' Aug. 1, 1871. The sections nevertheless are poor compared with that at *Ledbury*; and the only one of them worth consideration is that at *Perton*, where we see only 16 feet 11 inches of rock in stratigraphical succession. Mr. Brodie, however, was very successful in finding fossils. In "Olive shales" at the base of the quarry he found *Pterygotus Banksii,* and three species of *Eurypterus,* determined by Mr. Woodward. He also discovered a nearly entire specimen of a new species of *Eurypterus,* named by Mr. Woodward *E. Brodiei,* and described by him before the British Association at Liverpool, 1870.[1] I may here state that these Perton beds rest on the Downton Sandstone proper. I obtained a specimen of the carapace of a *Pterygotus* from yellow sandstone, lying underneath the "olive shales" of Mr. Brodie, and not now exposed. The Perton beds also contain many remains of carbonized Plants, and the seed-vessels regarded by Dr. Hooker[2] as Lycopodiaceous have been found therein. It may interest our readers to state, that the original specimens from which these seeds of land-plants were determined, were found years ago by Mr. Strickland and the writer of these notes, at Gamage Ford,[3] on the south side of the Woolhope anticlinal. The "Bone-bed" is found near Gamage Ford; and from shales closely connected therewith I obtained some beautiful specimens of the shields of *Scaphaspis,* which appear to be the same as *Scaphaspis ludensis* of the Lower Ludlow Rock of Leintwardine. With these two occurred fish-spines and portions of the carapace of *Pterygotus.* The ichthyodorulites are in the cabinet of the Earl of Enniskillen.

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[1] This section was given to illustrate my paper in 'Quart. Journ. Geol. Soc.,' 1860, vol. xvi, p. 194; but unfortunately the engraver did not reverse the drawing, so that the engraving is there reversed. See also 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 154.

10.—PASSAGE-BEDS AT LINLEY, SALOP.

The most northerly extension of the Passage-beds in the Silurian region is probably at Linley, Salop, which I visited in company with the late Mr. George Roberts, who, in conjunction with Mr. John Randall, published a paper thereon in the 'Quarterly Journal of the Geological Society' (1863, vol. xix, p. 229, &c.). Sections along the Linley Brook, four miles north of Bridgenorth, show the positions of the beds. The Coal-measures there rest upon a denuded surface of red Passage-clays, the relics of the denudation of the Old Red Sandstone; and below these we have twenty feet of light-coloured grits, with remains of Plants and fragments of Crustaceans. The whole section through the Old Red clays down to a limestone in the Upper Ludlow is about eighty feet. *Lingula cornea* ranges from the red Passage-beds through the Downton beds down to some shales, with remains of Fishes, Crustaceans, and *Lingulæ,* which I believe to be the representative of the Ludlow Bone-bed. Flaggy beds with *Serpulites longissimus* represent here the Upper Ludlow Shales, which pass into limestone (Aymestry Limestone?). I do not think that any beds at Linley can be correlated with those of Trimpley, near Kidderminster, as was supposed, which are, I believe, higher in the Lower Cornstone series of the Old Red Sandstone, and are not Passage-beds.

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[1] Since figured and described in the 'Quart. Journ. Geol. Soc.' 1871, vol. xxvii, p. 261, with a woodcut. See also Trans. Woolhope Club, 1870, p. 276. Hereford, 1871.

[2] 'Quart. Journ. Geol. Soc.,' vol. ix, p. 12, and vol. xvii, p. 162.

[3] Ibid., vol. ix, p. 9.

11.—OLD RED SANDSTONE (LOWER CORNSTONES), TRIMPLEY, NEAR KIDDERMINSTER.

Some years ago I accompanied Mr. George Roberts on an examination of the strata exposed at Trimpley, two miles north-west of Kidderminster. I am not inclined to rank these strata as Passage-beds, as some suppose them to be, but as true Lower Old Red Cornstones. The lowest beds are seen at a place called Little Gayne. They are micaceous shales, and Mr. Roberts showed me a collection of plant remains from these, associated with the egg-packets of the *Pterygotus* (*Parka decipiens*). Portions of the carapace of this Crustacean I saw myself in these flaggy shales. Above these strata there come on, opposite the Church, a series of impure Cornstones, interstratified with greyish flagstones exactly like the beds at Leyster's Pole, near Leominster, and those on the Bromyard Road, north-west of the great Cradley Quarries, near Malvern, which have yielded so many fish-remains to myself and others. These strata at Trimpley afforded numerous remains of *Pterygotus*, *Leptocheles*, *Cephalaspis Lyellii*, *Pteraspis rostratus*, and abundant plant remains. The egg-packets of *Pterygotus* were more numerous than I ever saw them in any other locality.

12.—OLD RED SANDSTONE (LOWER CORNSTONES), NEAR CRADLEY, MALVERN.

I have walked some hundreds of miles in my lifetime in endeavouring to discover a section showing a good passage into these strata, but have not yet succeeded. The ground is always more or less broken by faults, with a brook running on the line of fault, or obscured more or less on the point of junction. I have, however, little doubt that the beds at Trimpley, Leyster's Pole, near Leominster, and on the Bromyard Road near Cradley, are on the same general horizon, that they lie considerably above the Passage-beds proper, and are part and parcel of the Old Red Sandstone, whatever may be the fossils which they and their allied Passage-beds have yielded.

There are, or were, some years ago, two small quarries worked, one on the right and the other on the left of the Bromyard Road (about a mile north-west of the great Cradley quarry, on the summit of the hill, known as 'Cradley quarries'). These quarries are worthy of note. The quarry on the right, or East, which is a little higher in the series than that on the left, or West, has, on several occasions, yielded the remains of *Pterygotus*. The mineral character of this rock is that of greyish flags with impure cornstone concretions. Vegetable remains are nearly as abundant as they are at Trimpley, the beds also contained '*Parka decipiens*.' *Pteraspis*, *Scaphaspis*, and *Cephalaspis* are found here, and it was from this quarry that Mr. Ray Lankester obtained the specimen of

Pteraspis with scales attached, an account of which was communicated by him to the Geological Society in March, 1864 (see Quart. Journ. Geol. Soc., vol. xx, p. 194, &c.).

The quarry West of the road, and opposite the Old Farm House near the East quarry, is lower in the series by a few feet than the other, and the flags and Cornstones therein are full of remains of *Pteraspis*, *Cephalaspis*, and here and there traces of Crustacean chelæ and portions of carapaces. Specimens of these remains may be seen at the Museum at Worcester, and at the College at Malvern, also in Dr. Grindrod's collection at Townshend House, Malvern.

It is almost impossible to distinguish these beds, as far as carbonaceous markings and mineral aspect goes, from similar beds at Rowlestone, and Cusop, Hay, which are higher in the series of the Old Red Rocks.

13.—Old Red Sandstone (Lower Cornstones), Pontrilas, and Monmouth Cap, Herefordshire.

The Cornstone beds of the Old Red Sandstone commence nearly at the base of that formation, as seen near the railway-cutting at Wall Hills near Ledbury, where their position, as regards the Passage-rocks and Upper Silurians, may be studied. But even here there is a fault across the Passage-beds on the line of the River Leddon, and we have the consequent denudation and obscurity. Ascending upwards we find higher Cornstone groups, interbedded with marls, sandstones, and flagstones.

With no Silurian base to give us a starting point within many miles, we have only fossils to guide us as to the position of the strata exhibited near the Station at Pontrilas on the Hereford and Abergavenny Railway. Years ago, when the railway arch was building at Pontrilas, I saw a portion of a Fish, either *Pteraspis* or *Cephalaspis*, built into the wall; and afterwards my friend Mr. Thackwell and myself obtained fragments and plates of these Fishes and portions of the carapaces of Crustaceans from the loose *débris* in the quarry. Plant remains occur here; and it was from the equivalent beds near Ewyas Harold Castle, I believe, that Dr. McCullough and Mr. Salter obtained the remains of a gigantic *Pterygotus*.[1]

The sections here are difficult to follow out, owing to the lanes, &c., being so much obscured; but a walk from the quarry at Pontrilas Station by the Common of Ewyas Harold will lead the geologist to a Cornstone quarry yielding remains of *Cephalaspis* and *Pteraspis*. When the position of this quarry is compared with that of others on the opposite side of the River Munnow, above Monmouth Cap, and near Grosmont, the geologist will have little doubt that these Cornstone beds overlie the *Pterygotus*- and plant-bearing rocks of the Pontrilas Station.

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[1] *Pterygotus taurinus*, Salter, see pp. 75 and 76 of this Monograph.—H. W.

14.—ROWLESTONE SECTION, AND CUSOP BEDS NEAR HAY. FLAGSTONES OVERLYING THE LOWER CORNSTONES.

The geologist who wishes to study the correlation of these strata should first visit the town of Hay in Breconshire.

In that interesting district the Old Red Sandstone is denuded into lofty hills, with the Wye flowing on the line of denudation between them and the Radnorshire Silurians, upcast on the north and north-east.

Descending downwards from the upper crests of the "Brownstones" of the Black Mountains, and where portions of Old Red conglomerate still linger, we pass from Brownstones into thin Cornstones (Upper Cornstones), in which, only last summer, in company with Mr. Thomas, of Hay, I detected a portion of the dermal plate of a *Scaphaspis*. These Cornstones overlie and pass downwards into greenish and grey sandstones, with beds filled with layers of carbonaceous matter. Years ago speculations were entered into for sinking for coal on the east side of the ravine above Cusop, two miles south of Hay, and much money was sunk in these equivalents of the Rowlestone beds.

Below these flaggy beds (Cusop carbonaceous beds) there are other Cornstones, as seen in the section between Hay and Mouse Castle, and from these Cornstones came the large Fish spine exhibited by myself at the late meeting of the British Association at Edinburgh (1871), and named *Onchus major* by Mr. Etheridge, as being the largest known spine from the Lower Old Red yet discovered.[1] To the north-west of the town of Hay the lower beds of the Old Red with greyish sandstones and carbonaceous remains pass into the Upper Silurians of Radnorshire.

Now, he who examines the Rowlestone district near Pontrilas and Abergavenny, and observes how, as near Hay, Cornstones pass upwards and are overlain by flaggy beds with carbonaceous remains, these flaggy beds always occupying a particular horizon, will have little doubt in correlating the Rowlestone and Cusop flags as belonging to the same rock series, and in concluding that they belong to an upper Cornstone series and not to the lowest. In short, they form a line of demarcation between the Lower Cornstones and the Upper thin Cornstones and Brownstones which are so unfossiliferous throughout all the region of the Old Red of the West of England. On the summit and flanks of Rowlestone Hill, south of Ewyas Harold, Herefordshire, these grey flags have been quarried. They furnished a new species of *Stylonurus* (*St. Symondsii*), which is not unlike *St. Powriei* of the Devonian of Forfarshire, besides other remains of Crustaceans found by Dr. McCullough of Abergavenny, such as *Præarcturus gigas*, Woodward, &c. I have seen Fish remains in strata overlying these Rowlestone Rocks among the Black Mountains, and on the Darren, but the above are the newest relics of Crustaceans in the Old Red proper of which the writer is aware.—W. S. S.

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[1] While staying at Penzance I have seen, in the Geological Museum of the Institute, portions of Fish-spines from the Cornish Polperro beds which are associated with numerous remains of *Scaphaspis* and *Pteraspis*, like *Onchus major* in structure.—W. S. S.

Genus 2.—Slimonia, *Page*. 1856.

Species 1.—SLIMONIA ACUMINATA:—Salter, sp., 1855. Plates XVII—XX.

Himantopterus acuminatus, *Salter*. Quart. Journ. Geol. Soc. 1855, vol. xii, p. 29, fig. 4.
—— maximus, *Ib.* Id., p. 28, fig. 3.
Slimonia acuminata, *D. Page*. Advanced Text-book, 1856, p. 135, fig. 3.
Himantopterus acuminatus, *Ib.* Id., 2nd edition, 1859, p. 163, figs. a. b.
—— —— *Ib.* —— p. 159, fig. 2.
Pterygotus acuminatus, *Salter*. Mem. Geol. Surv., Mon. I., 1859, p. 57, plates ii, xiii, figs. 1—4, xv, fig. 1.
Slimonia acuminata, *H. Woodward*, 1863. Intellectual Observer, vol. iv, p. 229, plate and woodcuts.

Slimonia acuminata is the largest species found at Logan Water; and its generic name has been justly given to it in honour of Mr. Robert Slimon, who has, for more than twenty years, laboured most assiduously, at Lesmahago, to perfect our knowledge of this ancient and interesting order of Crustacea.

If we compare the figures of specimens given on Plates XVII to XIX, accompanying this Monograph, with those published in 1859 by Messrs. Huxley and Salter, we shall the better be able to understand and appreciate the vast amount of additional information which we now possess, the result of Mr. Slimon's energetic labours.

Plate XVII represents the most perfect example known; and will serve to convey a very correct idea of the relative proportions and structure of *Slimonia* as compared with the preceding genus *Pterygotus*.

The specimen in this plate has its *ventral* aspect exposed, and, therefore, we do not see the large trapezoidal carapace with its prominent marginal eyes (figured in Plates XVIII and XIX); but we notice the elongated heart-shaped lip-plate or metastoma (*m*) in the centre, covering the buccal cavity; the pair of minute and simple antennæ (2, 2, and detached fig. 3), which in this genus seem to take the place of the great chelate antennæ seen in *Pterygotus* (figured repeatedly in the plates which illustrate Parts I and II of this Monograph); the three pairs of simple many-jointed and spinose endognaths (3, 4, 5, and detached fig. 4); and the great swimming-feet or ectognaths (6, 6) with their broad basal joints serving evidently as powerful jaws; also the thoracic plate or operculum with its tongue-shaped median plate (7, *c*) *in sitû*, covering the first and second thoracic rings. The six broad thoracic segments, followed by six narrow abdominal somites, the last four of which are almost quadrangular in form, and terminated by a finely pointed spear-shaped tail-plate or telson, contrast markedly with the more robust and compact body in *Pterygotus*, with its rounded head-shield and great chelate antennæ.

The Head-shield (Pl. XVIII, fig. 2; Pl. XIX, fig. 1) in general form is oblong, the sides slightly swelling for about two thirds of the length, and contracting about the anterior third to again expand slightly at the anterior angles, where the prominent oval eyes are placed (*o*, *o*); the front border is somewhat rounded and, as well as the sides, crenated, or rather tuberculated along the edge.

The posterior border is incurved, and the lateral angles rounded. A kind of double tuberculate border is conspicuous down the sides of the head, the tubercles being elongated, while on the arched front border there are three or four rows. Two short minute keels, one on either side of and close to the median line, mark the hinder border of the head, and are also repeated on the posterior edge of each of the first six body-segments.

The Ocelli.—The two larval eye-spots (ocelli, *l*) are distinctly to be seen near the centre of the head-shield, and about one third of its length from the front border.

The Compound Eyes.—The facets composing the great compound marginal eyes can be not unfrequently clearly seen with a hand magnifying-glass.

Mr. Erxleben has endeavoured to give on Pl. XIX, fig. 2, a representation of the compound eye in *Slimonia*, magnified four times, but the facets are drawn upon rather too large a scale. They measure with the micrometer one tenth of a millimètre each.

Head-shields of *Slimonia* are very numerous both in the British Museum collection and in the Museum of Practical Geology, Jermyn Street.

That on Pl. XIX, fig. 1, measures 5¾ inches in greatest breadth and 6¾ inches in greatest length. That on Pl. XVIII, fig. 2, is 2¾ inches in breadth and 3¼ inches in length.

The head of *Slimonia* was very well known to Mr. Salter at the time of the publication of the 'Geological Survey Monograph,' as appears from the figures given on pl. ii accompanying his description, and from a woodcut in the text at p. 63. Mr. Salter gives an outline of a head measuring 6¼ inches in breadth and 7½ inches in length from the anterior to the posterior border. He does not notice the larval eye-spots on any of the Eurypterida; they have, however, been observed in *Eurypterus remipes* by Professor James Hall, in America.[1]

No ornamentation of any kind has been detected upon the general surface of the head-shield.

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[1] 'Nat. Hist.,' New York, Part iv; 'Palæontology,' vol. iii, plates 80—84, pp. 382—419.

The Body-rings are twelve in number, exclusive of the telson, or tail-plate. Of these the first, or anterior, six are reckoned, as in *Pterygotus* (see Parts I & II), as thoracic, and the remaining six as abdominal somites.[1]

Thoracic Segments.—In these somites the breadth greatly exceeds the length, the fourth segment being nearly six times as broad as it is long.

In the large and very perfect specimens figured on Pl. XVII the proportions of the thoracic segments are as follows :—

	No.	Breadth.		Length.
1st Segment	(8)[1]	5 inches	by	7 lines.
2nd ,,	(9)	5½ ,,	,,	10 ,,
3rd ,,	(10)	5¾ ,,	,,	11 ,,
4th ,,	(11)	6 ,,	,,	13 ,,
5th ,,	(12)	5½ ,,	,,	12 ,,
6th ,,	(13)	4½ ,,	,,	12 ,,

The posterior margin of the six anterior segments is ornamented, like the hinder border of the head, with two small keels or ridges upon their dorsal surfaces,[2] one on either side

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[1] These figures *in brackets* will be found to agree with the figures placed against each segment in the plates of this Monograph, and also with the Roman numerals placed upon each segment in the restored figures in Plates VIII and XX.

They are intended to remind the student that the head-shield is not a *simple segment*, but is composed in the Eurypterida of *at least seven* coalesced segments, each represented by a pair of appendages.

The hindmost of these seven coalesced segments, however, bears the opercular plate, as in the modern *Limulus*, and is considered to be equivalent to the first thoracic somite, as in the Xiphosures.

There are then only six *true cephalic somites* remaining in the head-shield of *Pterygotus*, whilst in *Limulus* there are clearly seven. This is explained by assuming that the somite bearing the antennules in *Limulus* is wanting or aborted in *Pterygotus*. (See ante, p. 43.)

Following out this assumption that the antennules were aborted, we have everywhere spoken of the first pair of appendages as the *antennæ*. (See p. 43.) [See also 'Quart. Journ. Geol. Soc.,' 1866, vol. xxiii, p. 33.] The figures and Roman numerals, therefore, express the *actual number* of segments present, which are represented by paired appendages, not the theoretical seven cephalic, and seven thoracic, and seven abdominal segments = twenty-one. (See Introduction, Part I, pp. 4—6.)

The absence of a number corresponding to this assumed aborted segment has inadvertently led to two errata. Thus in the explanation to Plate VIII the segment marked xiv is erroneously classed as thoracic instead of abdominal, and the error is repeated in Part II, pp. 63 and 65, the segment (14) being there also bracketed as thoracic.

In Part I, p. 63, I have said that "in this case" [that is, if we assume that the first thoracic somite is coalesced with the head—then] "only the first six anterior somites will be counted as thoracic, the posterior six will be reckoned as abdominal, and the 'telson' will make up the twenty-one segments."

[2] They are seen as impressions—through the compression of the segments—in the specimen figured in Pl. XVII, which exhibits a *ventral* aspect of *Sl. acuminata ;* but these carinæ are strictly confined to the *dorsal* surface of the segments.

of the median line, each composed of from three to four tubercles arranged in a line, with their blunt points directed backwards. The sides of the anterior segments are rounded and the hinder border but slightly incurved, like the posterior border of the head. A line is usually seen crossing each segment parallel with its anterior border, and indicating the portion of each body-ring inserted beneath that of the preceding segment. At first sight there does not appear to be any trace of the squamate ornamentation, covering the surface of the segments, so characteristic of other members of this sub-order; but, although rarely seen, it may occasionally be detected upon the anterior border of the somites; the plicæ are, however, very minute, and not at all conspicuous as in *Pterygotus anglicus.*

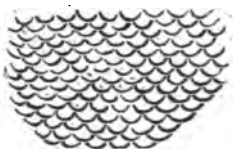

FIG. 30.—Plicæ, greatly magnified, from an abdominal ring in *Slimonia acuminata,* Salter, sp.

The foregoing measurements do not represent by any means the largest-sized body known. A detached body, in which the first six somites (thoracic) are conjoined, preserved in the British Museum, gives the following measurements:—

		No.	Breadth.			Length.	
1st	Segment	(8)	8½	inches	by	1	inch.
2nd	„	(9)	8½	„	„	1¼	„
3rd	„	(10)	8¾	„	„	1½	„
4th	„	(11)	8	„	„	1½	„
5th	„	(12)	7¼	„	„	1¼	„
6th	„	(13)	6	„	„	1¼	„

Abdominal Segments.—These commence with the fourteenth somite, and, in the specimen figured in Pl. XVII, measure as follows:—

		No.	Breadth.			Length.	
7th	Segment	(14)[1]	3½	inches	by	1	inch.
8th	„	(15)	2¾	„	„	1½	„
9th	„	(16)	2	„	„	1½	„
10th	„	(17)	2	„	„	1¾	„
11th	„	(18)	1¾	„	„	2	„
12th	„	(19)	1¾	„	„	2¼	„

The sides of these posterior segments are nearly straight; they have no keel-markings, as is the case with the thoracic segments, nor are their borders produced at all.

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[1] See foot-note [1], *ante,* page 107.

The surface of all the segments is much crumpled and creased, clearly indicating that the covering of the body was far less robust than in *Pterygotus anglicus*, Agassiz.

The *Telson* or tail-plate (20) is a large, somewhat oval plate, terminated by a long slender finely pointed spine, often nearly as long as the telson itself. The length without the spine, in fig. 1, Pl. XVII, is three inches, and, including the spine, 5¾ inches. The greatest breadth is 2¼ inches; the breadth at its articulation with the last segment 1¼ inch. The lower side of the telson is somewhat hollowed, whilst upon the dorsal surface it is marked by a strong median keel which is continued down the centre of the tail-spine to its extremity.

The margin of this tail-joint is ornamented with a serrate or tuberculate ornamentation near the base (like that on the margin of the head), which is often seen to be continued down the sides of the terminal spine.

We have already referred to the ocelli and compound eyes which occupy the dorsal aspect of the head-shield; and must now describe those appendages which are grouped around the mouth on the ventral aspect of the body.

The Antennæ (Pl. XVII, figs. 1, 2, 2, and 3; Pl. XVIII, figs. 1, 2, 2). This pair of appendages is very small; and, from the fact of their always lying closely folded down on either side of the mouth, they had remained unnoticed by previous observers until pointed out by me in an account of this genus published in 1863.[1]

The subjoined woodcut (fig. 31) shows the usual position in which they are found. In Pl. XVII, fig. 3, the palpus is turned in the opposite direction with regard to its basal or attached portion (endognath) to that in which it usually occurs.

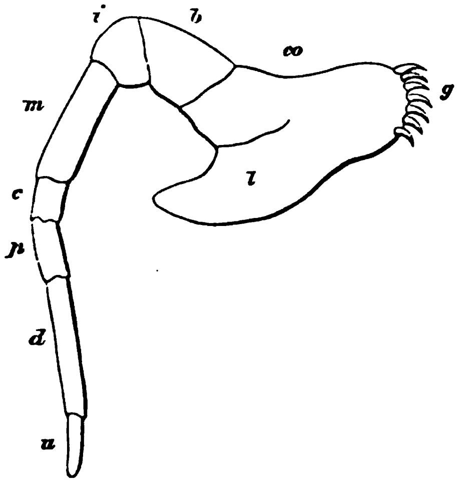

FIG. 31.—Antenna of *Slimonia acuminata*, Salter, sp. (Natural size).

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[1] See 'Intellectual Observer,' vol. iv, 1863, pp. 229—237; woodcut K, p. 235.

The first or coxal joint (*co*) is the largest, measuring 9 lines in its greatest length and 9 lines in its greatest breadth. The tongue-shaped extension (*l*) unites it to the head and to the muscles by which the palpus (*b*—*u*) and the endognath (*g*) are moved.

The mandibular portion (*g*) is armed with from 7 to 8 sharp and recurved teeth about 1 line in length. From the upper side of the endognath the palpus takes its rise: (*b*) the *basos* measures 6 lines in length and four lines in breadth: (*i*) the *ischium* commences 4 lines in breadth, but contracts to 2 lines at its distal end; it is 3 lines in length: the four succeeding joints are nearly cylindrical in form: (*m*) the *meros* is 8 lines in length and 2 lines in breadth: (*c*) the *carpus* is 3 lines in length and 2 broad: (*p*) the *propodos* is 4 lines long and 1½ broad: (*d*) the *dactylus* is 9 lines long and 1 line broad: (*u*) the *unguis* or terminal joint is 4 lines long and 1 line broad.

The structure of this pair of appendages differs widely from the antennæ in the preceding genus (see Parts I & II), and seems to indicate a close affinity with *Eurypterus* (to be presently described).

Instead of the powerful chelate appendages with which the front of the head in *Pterygotus* was armed, we find in *Slimonia* only this pair of minute and simple eight-jointed antennæ which could merely have served as feelers (and accessory endognaths), not as organs of prehension.

Another essential point of difference to be noted in these organs as compared with those of *Pterygotus* is in the fact that the chelate organs in *Pterygotus* do not perform the functions of manducation with their basal joint, but only subserve the purposes of prehension, and to convey food to the mouth, being placed in front of the buccal orifice.

In *Slimonia* the small slender antennæ are expanded at their base so as to form an additional pair of jaws (endognaths), and are, therefore, directly in relation with the buccal orifice.

These distinctions are of the highest importance in considering which of the two pairs of antennary organs has been suppressed in the Eurypterida.

If we take *Pterygotus* by itself, the fact of its antennæ not being furnished with a mandibular basal joint would lead to the inference that these great chelate organs of prehension were equivalent to the *antennules* in *Limulus*, and that the antennæ were suppressed.

If, on the contrary, we take *Slimonia* by itself, the fact of its antennæ being furnished with maxillated basal joints would favour the inference that they were equivalent to the *antennæ* in *Limulus*, and that the antennules were suppressed.

But we so frequently find the same pair of organs in closely allied families, and even genera, of living Crustacea so greatly modified as to present scarcely a character in common save their corresponding position, that we may well suppose the differences of form and office above described to be due, not to a difference in the organs, but to diversity of habits in the genera; suggesting the more actively predacious character of *Pterygotus* as compared with *Slimonia*, and probably that the food of the former consisted of quick-swimming fishes and cephalopods, whilst the latter preyed upon minute or sedentary animals, or was possibly a carrion-feeder, like so many of its representatives at the present day.

If we really knew such to be the actual function required to be performed in each case, the organs in question could hardly be better adapted for their respective tasks.

Endognaths (= Mandibles and Maxillæ) (Pl. XVII, figs. 1, 3, 4, 5, fig. 4; and Pl. XVIII, figs. 1, 3, 4, 5).—Following next after the antennæ we find three pairs of endognaths, with a pair of eight-jointed palpi to each. There is a very good woodcut (fig. 7) of one of these on p. 62 of the Survey Memoir on *Pterygotus*, and upon p. 63 of the same work is a woodcut of a head with parts of two of the palpi preserved nearly *in sitû*.

We figure a large detached endognath on Pl. XVII, fig. 4, the palpus of which measures four inches in length.

The *coxa* or basal joint (*co*) is roughly quadrangular in outline, and is 1½ inches in both length and breadth; the inner border (*g*) is 8 lines broad and is armed with about fourteen sharp and curved teeth, which at the upper end are nearly 2 lines in length, but diminish rapidly to the lower part of the mandible, where they are little more than bristles (as in the endognath of *Limulus*); the lower border (*b*) is nearly square, but half an inch narrower than the upper border; by it the appendage was attached to the head; a few scattered scale-markings are disposed over the upper free border.

The *palpus* (*b-u*) in this specimen seems to be turned the reverse way; it lies with its spiny border downwards and its point directed outwards; usually its upper border is spinose and the recurved terminal spine is directed inwards, as in the accompanying woodcut, fig. 32, p. 112.

The *basos* (*b*) is an oblong joint one inch in length and three quarters of an inch broad; it has a few scale-markings on its upper border.

The *ischium* (*i*) measures one inch along its longest border, but only half an inch along its spinose upper border, being sharply bent upwards; it is three quarters of an inch broad.

The *meros* (*m*) is three quarters of an inch long and the same broad; its distal end and that of the four succeeding articulations is fringed with spines.

The *carpus* (*c*) is three quarters of an inch long and seven lines broad.

The *propodos* (*p*) is five lines long and six broad.

The *dactylus* (*d*) is three lines long and four broad.

Between this joint and the terminal claw (*u*) there is a small joint (*t*) two lines long and four broad (seen also in the woodcut, fig. 32, p. 112); the claw (*u*) is half an inch long, and strongly recurved.

The accompanying woodcut (fig. 32, p. 112) represents the largest endognathary palpus with which I am acquainted. It measures seven inches in length and two inches in greatest breadth. The five distal joints appear to have been fringed with spines at their lower and outer borders, which are more sharply pointed near the extremity. The form and proportion of the five distal joints agree very closely with those in the palpus drawn on Pl. XVII, fig. 4; but the *ischium* and *basos* differ considerably, and appear to be squeezed together. The same squamate markings are seen on the surface. (See Woodcut, fig. 32.)

These mouth-appendages appear to be much more robust than in *Pterygotus*, and must have served, not only as powerful jaws, but also to retain and bring within reach of the mandibles the living or dead substances to be devoured.

Swimming-feet (Ectognaths) (Pl. XVII, figs. 1, 6, 6, and Pl. XVIII, figs. 1, 6, 6).—The largest swimming-foot of this species with which I am acquainted is a detached example in the British Museum. This specimen measures ten inches from the crest of the maxilla to the terminal palette, the swimming-foot itself measuring six inches in length. The position and form of these organs are well seen, *in situ*, in Pl. XVII, fig. 1, and in the detached appendages figured on Pl. XVIII, fig. 1.

Coxa.—This joint in form may be roughly compared to a right-angled triangle, the inner or mandibular border and the base forming the rectangle. The base measures 2½ inches in breadth, to the outer angle of which the great swimming-foot is seen to be attached, the outer and longest side of the triangle measuring 4½ inches; the upper end, which forms the mandible, is contracted three inches from the base, where it measures only ten lines in breadth; the mandibular border is 1¼ lines broad, and beset with 14 nearly equal-sized teeth one line in length. Some minute squamæ are observable upon the surface of this joint.

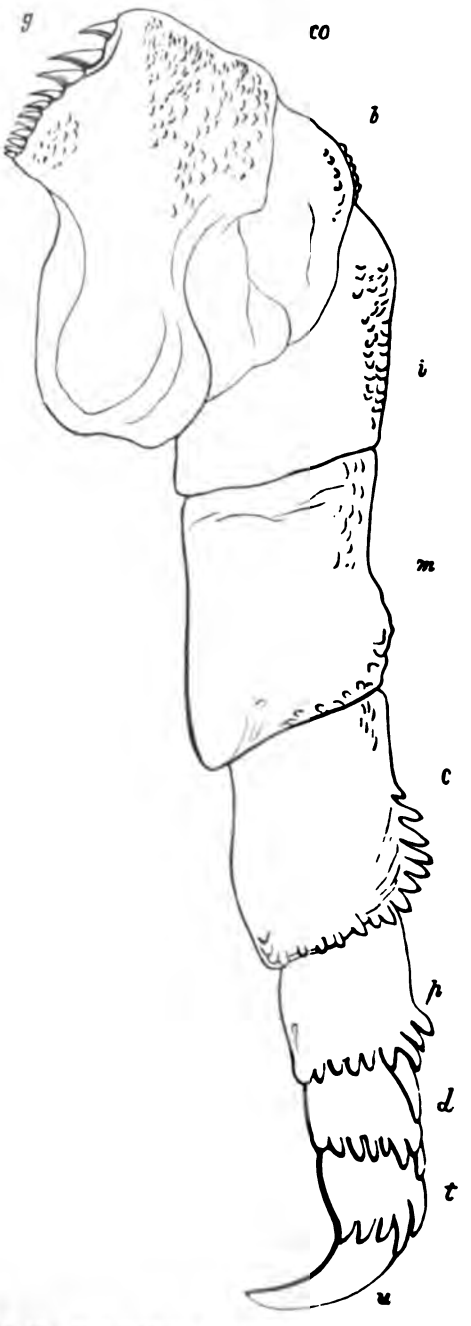


FIG. 32.—Endognathary palpus of *Slimonia* (natural size), U. Silurian, Lesmahagow, Lanarkshire. Original specimen in the Britisih Museum.

Basos.—This is a small segment, four lines only in length, inserted at its proximal end into the external angle of the coxal joint, where it is nine lines broad and expanding laterally at its distal end to 1¼ inches, so as to embrace in its cup-shaped and rounded lower border the conjoined *ischium* and *meros.*

The *Ischium* and *Meros* resemble an oblong square divided diagonally, the *ischium* having its upper and proximal border 11 lines broad, and its lower end cut off by the distal termination of the meros, which is one inch broad, whilst the proximal end of the meros is in like manner cut off by its union with the *ischium.*

The *ischium* along its inner longitudinal free border measures one inch; the *meros* along its outer rounded free border measures 1½ inches; the conjoined border measures 16 lines in length.

The *carpus* resembles the *basos* in form; it is ten lines broad at the upper and five lines long and slightly expanded at the lower border, which is curved so as to afford a better articulation to the *propodos.*

The *propodos* is two inches long and ten lines broad, and its sides are nearly parallel; it is excavated at the lower extremity, so as to admit the insertion of the *dactylus.*

Between these two on the inner side is a small triangular plate intercalated, four lines in length and three in breadth; a similar plate is known to exist in *Eurypterus* and other forms.

The *dactylus* is 1½ inches long and half an inch broad; near its termination a minute plate (*unguis*) is inserted; a similar terminal plate is noticed by Professor Hall in *Eurypterus.* The border of these joints is sometimes seen to be slightly crenated.

Post-oral Plate or *Metastoma* (Pl. XVII, fig. 1, *m*; Pl. XVIII, fig. 1, *m*).—This plate is seen *in sitû* in Pls. XVII and XVIII; the largest lip-plate of *Slimonia* known is that figured in the subjoined woodcut (fig. 33) of the natural size. It measures 5½ inches in length and 1¾ inches in greatest breadth, the lower part being only ten lines broad. Its greater length as compared to its breadth distinguishes it at once from the metastoma of *Pterogotus,* with the remains of which *Slimonia* is commonly found associated.

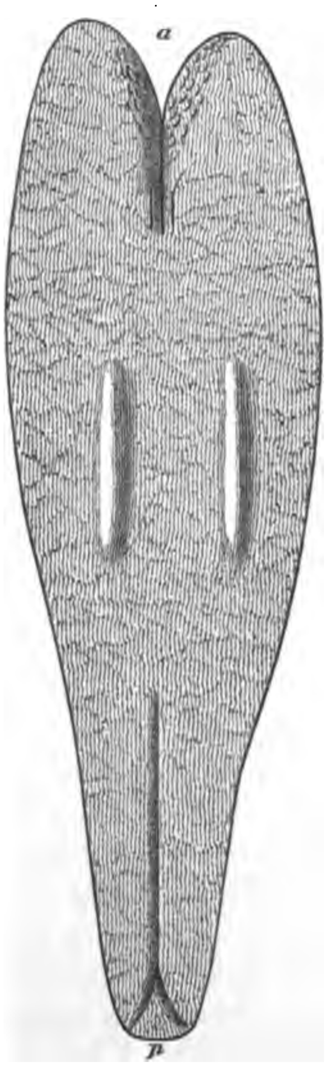


FIG. 33.—Largest lip-plate of *Slimonia acuminata* known, from Upper Ludlow Rock, Lesmahagow. Original preserved in the British Museum.

The upper end (*a*) is deeply bilobed, the lobes elliptical and the notch very narrow; its greatest breadth (1¾ in.) is in the centre of the upper two thirds; the lower third is very narrow and has a raised keel down the centre, two inches long, which bifurcates at the hinder border. Near the centre of the widest part are two subcentral parallel ridges about 1½ inches long. A few scale-like markings are seen near the upper notched end of the lip-plate. This plate was, no doubt, attached along the line of the posterior median ridge and by its hinder border (*p*). It overlapped the inner borders of the great basal ectognaths, and served as a *mentum*, or lower lip, being attached behind, not in front of the buccal orifice, as is the hypostome in the Trilobita.

The Thoracic Plate or Opérculum (Pl. XVII, fig. 1, 7, *c*, and fig. 2; and Pl. XX, figs. 2, 3, & 4).—The displacement of this plate in the description of this species by Mr. Salter ('Geol. Surv. Mem.,' Mon. I, p. 59), where, as in the descriptions of *Pterygotus*, it is called "the conjoined epistoma and labrum," has already been referred to under *Pterygotus*. (See restoration after Mr. Salter, Part I of this Monograph, p. 27 and p. 39.) It is only necessary to point out that fig. 5, p. 59, of Mr. Salter's description (op. cit.) is identical in form with the plate seen *in sitû* on our Pl. XVII, fig. 1, 7, *c*; and that figured on p. 60, fig. 6 (op. cit.) is the tricuspid median appendage of a plate identical in form with that figured on our Pl. XVII, fig. 2, and is known to occupy the same relative position in the body of *Slimonia* as that seen *in sitû* (7, *c*) on the same plate in fig. 1. It is, in fact, homologous with the *operculum* of *Limulus* (Part I, Pl. IX, fig. 1, 8, and fig. 1, *c*), and is composed, as in *Limulus*, of the modified appendages belonging to the first thoracic somite, which in both *Limulus* and *Slimonia* is coalesced with the cephalon.

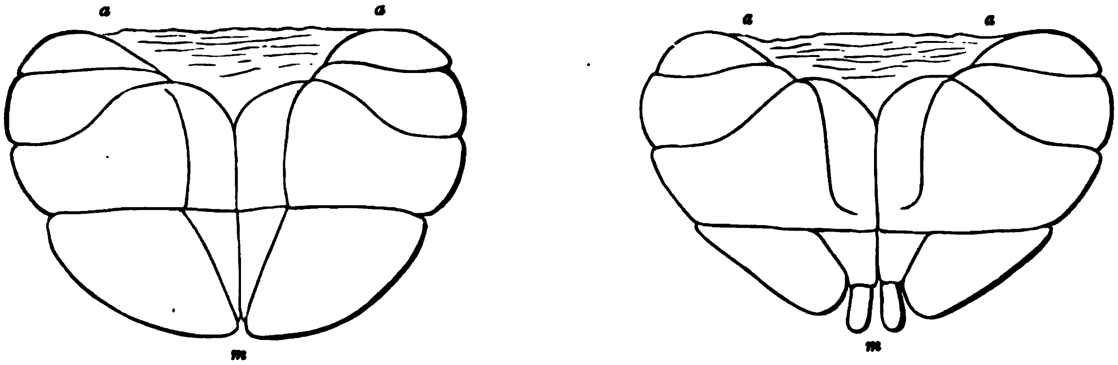
The thoracic plate seen *in sitû* in fig. 1, Pl. XVII, measures five inches from border to border, and is 1½ inches in length; it is divided into two lateral oblong pieces by a median lobe (*c*), which is 2¼ inches long and projects considerably below the rest of the lower free border of the plate. This median lobe in fig. 1 is broadest at its lower rounded extremity, where it is eight lines wide, contracting to six lines where it unites with the two oblong lateral pieces of the *operculum;* at its upper end it forms a small triangle, four lines long and four broad, from the apex of which a narrow double line extends to the upper attached border. Two diagonal lines take their rise from the upper triangular end of the median lobe (*c*), uniting with the upper border of the operculum one inch on either side of its central line.

The specimen figured on Pl. XVII, fig. 2, measures eight inches in breadth and 1¾ inches in length; the median lobe is 3½ inches long; its termination (*c*), instead of being rounded, as in fig. 1, is tricuspid, measuring one inch across the side cusps; the centre of the median lobe is ridged; the margins are slightly curved, and unite in a lanceolate termination half an inch from the anterior attached border. Instead of the two diagonal lines seen in fig. 1, three lateral lines are given off from near the lanceolate upper end of the median lobe, which, expanding on either side, reunite with each other, and so with the upper and inner attached border of the operculum one inch on either side the median line. A slight double border two lines broad surrounds the free margin of the lateral lobes of the operculum.

There is good reason to believe that both these forms of opercular plates not only belong to *Slimonia,* but to one species, namely, *Slimonia acuminata.*

How, then, can we explain the diversity in the form of the median appendage in the two opercula figured on Plate XVII?

If we refer again to its living analogue, *Limulus,* we shall find that in the Moluccan and American king-crabs the same parts are modified in the males of both species, namely, the antennæ and the median articulated appendages of the thoracic plate or operculum (see Pl. IX and Woodcuts, I, II, fig. 34), corresponding to the coalesced median appendage in *Slimonia.*[1]



I. II.

Fig. 34.—Operculum or thoracic plate of *Limulus polyphemus,* Linn. (living). I. Male. II. Female. *a, a.* Anterior attached border: *m* = median appendage.

At present we only know one form of antennæ in *Slimonia,* but the discovery of the two forms of thoracic plate (Pl. XVII, fig. 1, 7 *c,* and fig. 2; and Pl. XX, figs. 3 and 4) affords strong grounds for assuming that we have here evidence of the male and female of this fossil type.

The Branchiæ (Pl. XIX, figs. 3, 4).—In my account of *Pterygotus bilobus,* Salter, in Part II of this Monograph (pp. 66—68, Pl. XI, fig. 2; Pl. XII, figs. 1 *a,* 1 *d;* Pl. XIII, fig. 1 *h*) I have figured and described the branchial plates belonging to that species. Similar leaf-like organs of a larger size have been obtained at Lesmahagow, associated with *Slimonia,* some of which I figure on Pl. XIX, figs. 3, 4, of the natural size. They appear to be arranged in linear series, and were attached in single or double rows to the under surface of the body by their upper end, whilst their lateral and lower rounded leaf-like borders were freely bathed in the fluid medium in order to oxygenate the blood.

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[1] This median lobe is even more readily identified with *Limulus* if we take *Eurypterus* instead of *Slimonia* for comparison. In *Eurypterus* the division of the median lobe into two detached articulated appendages remains clearly visible, whereas in the other fossil genera these are coalesced.

This coalesced median appendage, with its broad lateral alæ, forming together the operculum, is really only the modified pair of appendages belonging to the first thoracic somite, the median pair of appendages (or coalesced lobe, as the case may be) corresponding to the endopodites, and the external alæ to the exopodites of an ordinary pair of Crustacean limbs.

This singularly modified pair of thoracic appendages perform the same office in *Limulus* as do the antepenultimate thoracic legs in the female lobster, or the last thoracic limb on each side in the male; in the former bearing the *oviducts,* in the latter the *vas deferens.*

These leaf-like appendages are highly vascular; they are about two inches in length and three fourths of an inch broad, but they vary in size, having probably been largest near the centre of the body, becoming smaller as they approached the sides.

In the adult living *Limulus* we find the operculum, or thoracic plate, takes its rise from, and is attached to, the posterior margin of the head-shield.[1] This plate bears on its upper and inner surface the reproductive organs, or ovaries, and is succeeded by five similar but more membranous plates bearing the branchiæ upon their inner surfaces. These five branchial plates are nearly hidden beneath the operculum when closely compressed. Each plate, however, represents the modified pair of appendages belonging to a corresponding thoracic somite.

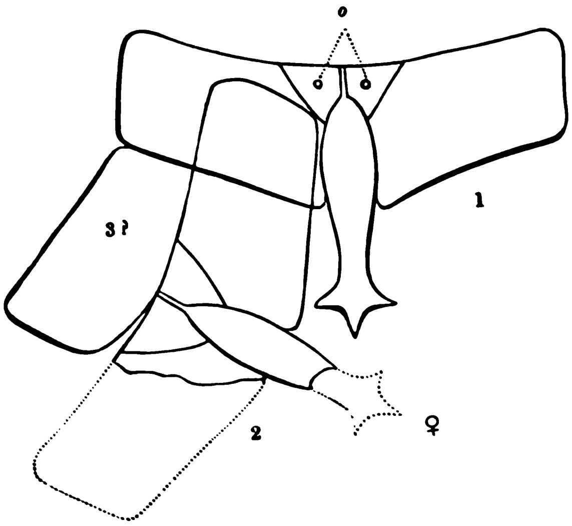

Fig. 35.—Opercula or thoracic plates of *Slimonia acuminata*, Salter, sp., found associated together.
1. The outer or *true operculum*, bearing the ovaries (*o*). 2. First branchigerous plate underlying 1, but now displaced.
3 ? Part of a third plate ?
Mr. Slimon considered this tricuspid form of plate to belong to the *female* of *Slimonia* because he has several times found it associated with masses of the eggs (called by Dr. Fleming *Parka decipiens*).

In *Pterygotus* and *Slimonia* we find the thoracic plate, or operculum, occupying the same position as in *Limulus*, and attached to the hinder border of the head. But as the segments in the Eurypteridæ are not coalesced as in the modern *Limulus*, but are well developed, the thoracic plate can therefore only cover and conceal the two first thoracic somites.

Supposing each of these (marked viii and ix in Pl. XX) to have borne a single or double row of branchiæ supported on two similar but more membranous plates, they might easily have lain concealed beneath the outer operculum.

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[1] With which the first thoracic segment is coalesced. This is also the case in *Pterygotus*, *Slimonia*, &c.

This latter point seems established on the evidence of specimens both in the Museum of Practical Geology and in the British Museum, showing *two* (or three ?) opercular plates of the same shape associated together, and evidently belonging to the same individual.[1]

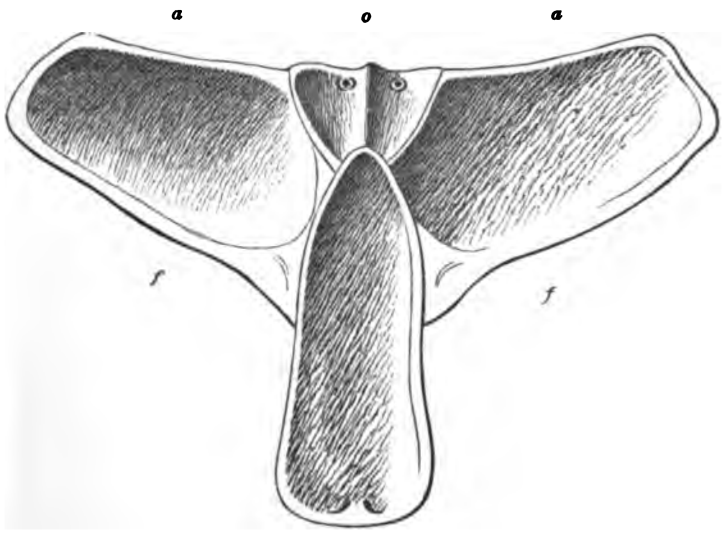

Fig. 36.—View of the inner side of an opercular plate of *Slimonia acuminata*, from Lesmahagow, Lanarkshire, in which the two reproductive openings are seen near the centre of the upper attached border (*a*, *a*) of the plate.

Two of these plates, moreover, exhibit two small rounded prominences, which, there can be little doubt, were ovarian openings. (See Woodcuts, figs. 35 and 36.)

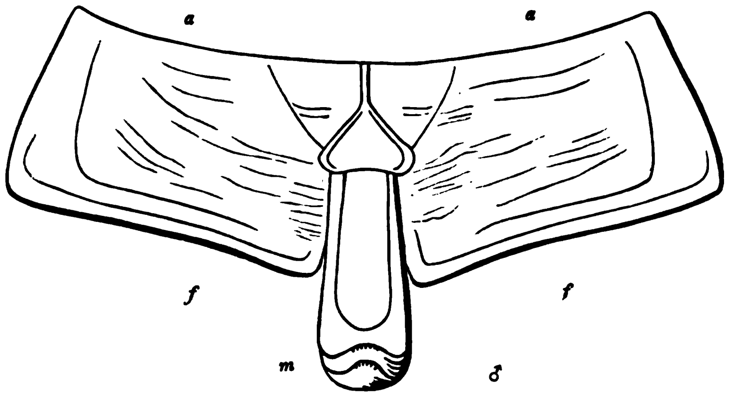

Fig. 37.—Thoracic plate or operculum of *Slimonia* ———— sp. ?, giving indication of the presence of branchigerous plates concealed beneath. *a*, *a*. Attached border. *f*, *f*. Free border. *m*. Median appendage.

This paucity in the number of pairs of appendages to the body-rings is a truly larval character, reminding one of the condition of the larval Decapod (see Part I, Plate IX, figs. 6 & 7), and of the still nearer larval *Limulus*, which, in its earlier stage, has appendages only to three of the thoracic somites.[1]

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[1] See 'Quart. Journ. Geol. Soc.,' 1867, vol. xxiii, p. 31. H. Woodward, "On the Structure of the Xiphosura and their Relationship with the Eurypteridæ."

In the two annexed diagram-figures of specimens preserved in the Museum of Practical Geology (figs. 37 and 38) the thoracic plate differs somewhat in form from that usually associated with *Slimonia acuminata;* they deserve to be recorded, therefore, on that account; but they also appear to give evidence that they conceal beneath them one or more branchigerous plates, the edges of which are seen at *m*, and along the lower border of the lateral alæ of the operculum (*f*, *f*).

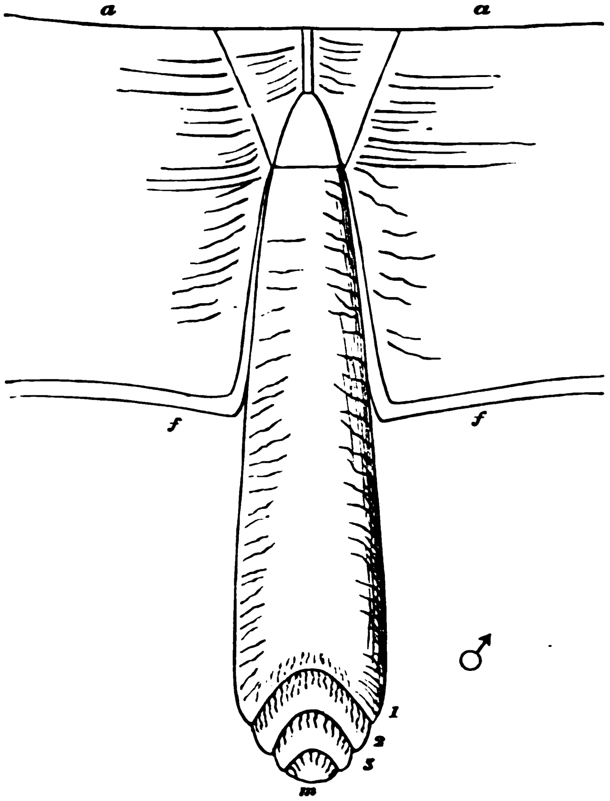

Fig. 38.—Thoracic plate or operculum—part of an almost entire specimen—of *Slimonia acuminata* (only the centre of operculum drawn), showing apparently three plates overlying each other. Length of alæ, 3 inches. Length of median appendage, 5 inches.

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[1] See 'Quart. Journ. Geol. Soc.,' 1867, vol. xxiii, p. 34. Also 'Sur le développement des *Limules*,' par H. Milne-Edwards, Société Philomathique, Nov. 10th, 1838. On "The Horsefoot Crab," by the Rev. S. Lockwood, Ph.D., in 'American Naturalist,' vol. iv, 1870, p. 257. Also Dr. A. S. Packard, junr., 'On the Development of the "King Crab," *Limulus polyphemus*,' read before American Association for the Advancement of Science, 1870, 'Geol. Mag.,' 1870, vol. vii, p. 491. 'Untersuchungen über Bau und Entwickelung der Arthropoden zur Embryologie und Morphologie des *Limulus polyphemus*,' von Dr. Anton Dohrn. Abdruck aus der 'Jenaischen Zeitschrift,' Band vi, Heft 4. (Received 30th September, 1871.—H. W.) And "Further Remarks on the Relationship of the Xiphosura to the Eurypterida and to the Trilobita," by H. Woodward, 'Quart. Journ. Geol. Soc.,' 1872, Part I, vol. xxviii, p. 46.

One other point which may be mentioned as favouring the conclusion we have arrived at, namely, that there were *at least two* thoracic plates, the one attached to the first thoracic segment coalesced with the cephalon, and bearing the reproductive organs; the other attached to the second (first *free*) thoracic somite and bearing the branchiæ[1]—is that some of these thoracic plates are closely covered with fine squamate markings, whilst others are entirely destitute of any kind of ornamentation upon their surface.

I do not think that this is due merely to the condition of preservation of the individual specimen; for if markings were present we should, from the fine-grained nature of the matrix, certainly find them either upon the intaglio or relievo side of the slabs, the specimens being nearly always obtained thus impressed, *in duplicate* as it were, in the matrix.

On the contrary, I am inclined to consider the presence of scale-markings in the one plate and their absence in the other to be due to the circumstance that the scale-marked plate is the outer or first thoracic plate (bearing the ovaries), whilst the smooth plate is the inner or second thoracic plate (the gill-bearing plate), which, like the inner plates to *Limulus* is thinner and more membranaceous than the external operculum.

Judging from the large series of detached portions of this species, preserved in the British Museum, and in the Museum of Practical Geology, Jermyn Street, the largest specimen of *Slimonia acuminata* known could not have exceeded four feet in length; and by far the greater number of individuals were less than three feet long. They cannot therefore be said to equal in size the largest species of the genus *Pterygotus*, which, no doubt, attained a length of at least five feet.

Besides the almost perfect specimen, figured on Plate XVII, which is about 26½ inches in length, there are three small and nearly entire examples of *Slimonia*, measuring respectively: 7¼ inches, 7 inches, and 5¾ inches in length, and 1½ inch, 1¼ inch, and 1 inch in breadth.

The hinder border of the head and each of the six anterior segments is marked in these young individuals with two small subcentral keels or ridges upon their dorsal surfaces.

The integument appears to have been extremely thin; no scale-markings are discernible, and the whole surface is much crumpled up.

Except that at this early stage the young of *Slimonia* seem to be much narrower in proportion to their length, the restored figures on Plate XX might serve to represent one of these small specimens. Portions preserved in section in the British Museum, and in the Museum of Practical Geology, indicate that the anterior segments in *Slimonia* were even more robust than in *Pterygotus* (see Part I, p. 41), whilst the posterior segments were nearly if not quite cylindrical.

Only one species of this singular genus is known, and its remains are, at present, confined to one locality, namely, the Banks of Logan Water, near Lesmahagow, Lanarkshire.

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[1] It is quite possible there may have been a third plate, also branchigerous.

The series of forms, already figured and described, and included in the genera *Pterygotus* and *Slimonia,* although differing among themselves in many important points of structure, have one common distinctive character, namely, the position of the large compound eyes.

In the genera *Stylonurus* and *Eurypterus,* and in the Xiphosura (to be described in Part IV), these organs occupy a more or less *sub-central* position upon the dorsal surface of the carapace, as is the case also in the Trilobita. In *Pterygotus* and *Slimonia,* on the contrary, the eyes are *marginal,* being placed upon the latero-anterior border of the head. The only form which, from the position of the eyes, can be compared with *Slimonia* and *Pterygotus,* is Hall's *Dolichopterus,*[1] an American form, in which the large compound eyes approach very near the latero-anterior angles of the carapace; but, nevertheless, they are *not marginal* eyes, but are really placed upon the dorsal surface of the head, as in *Eurypterus* proper, of which, indeed, Hall makes his *Dolichopterus macrocheirus* a sub-generic form.

For the greater convenience of the palæontological student, the diagnostic characters of each genus of the Merostomata will be given in a condensed form at the conclusion of Part IV.

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[1] 'Geological Survey of New York, Palæontology,' by James Hall, vol. iii, p. 414*, pl. lxxxiii, Albany, U.S., 1859.

A MONOGRAPH
OF THE
BRITISH FOSSIL CRUSTACEA
OF THE
ORDER MEROSTOMATA.

PART IV.

Genus 3.—STYLONURUS, *Page*. 1856.

To the acuteness and discrimination of Professor Page, F.G.S., we are indebted for the earliest indication of two very well-marked genera of Palæozoic Crustacea of the order Eurypterida, namely, *Slimonia* and *Stylonurus*.[1] *Slimonia* has already been figured and described in the preceding part of this Monograph (pp. 105—120), and *Stylonurus* in the 'Geological Magazine' (1864, vol. i, p. 197), and in the 'Quarterly Journal of the Geological Society' (1865, vol. xxi, p. 482).

During a visit to Scotland early in 1864, I spent a week with my friend Mr. James Powrie, F.G.S., at Reswallie, which enabled me to examine the localities in Forfarshire, whence the Devonian species of *Pterygoti*, *Stylonuri*, &c., have been obtained. Upon that occasion, and also upon a subsequent visit in 1867, I had the great advantage of studying, not only Mr. Powrie's fine collection of palæozoic fossils, but also the collections of Lady Kinnaird, at Rossie Priory, of the University of St. Andrew's, the Watt Institution, Dundee, the Natural History Museums of Arbroath and Montrose, the Andersonian and Hunterian Museums in the University of Glasgow, and the Museum of Science and Art, Edinburgh; besides the private collections of James Armstrong, Esq., and others, in both Edinburgh and Glasgow, containing many fine examples of these palæozoic

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[1] See Page's 'Advanced Text-Book of Geology,' 1856, p. 135, figs. 2 and 3, and subsequent editions. Mr. Page, however, has published no descriptions of these fossils, and his woodcut, figures, and explanations appended thereto are only partially correct.

Crustacea. During my last visit to Scotland, in August, 1871, the only additional materials for my Monograph which I then obtained consisted of the specimens of *Eurypterus Scouleri* from my friend Mr. Powrie's collection.

The most important characters by which the genus *Stylonurus* is distinguished are the peculiar form of the carapace, the great length of the telson or terminal joint (in *S. Powriei* one third the length of the entire animal), and the substitution of two pairs of long, slender, oar-like jaw-feet, instead of the single pair of broad, short, natatory organs more usually met with in this group.

Species 1.—STYLONURUS POWRIEI:—H. Woodw. Pl. XXI, fig. 1 (and fig. 2 ?).

STYLONURUS, *Page.* British Assoc. Report, Glasgow, 1855, p. 89.
— POWRIENSIS, *Page.* Advanced Text-Book of Geology, 1856, p. 135, fig. 2.
— POWRIEI, *Page.* Op. cit., 2nd edit., 1859, p. 181, fig. 3.
— — *H. Woodw.* Brit. Assoc. Report, Bath, 1864, p. 73.
— — *H. Woodw.* Quart. Journ. Geol. Soc., 1865, vol. xxi, p. 482, pl. xii, fig. 1.

Stylonurus Powriei was obtained from the Old Red Sandstone of the Turin Hill range, near Pitscandly, in Forfarshire, by Mr. James Powrie, F.G.S., of Reswallie, after whom it has been named.

The impression and counterpart of *S. Powriei* being only on sandstone, and, in all probability, the interior side of the upper surface, do not afford such good material for description as the specimens of the other species to be hereafter mentioned.

Dimensions.—The Carapace measures 2 inches 3 lines across at its posterior border, and 2 inches 7 lines in its greatest breadth, and 2 inches in length. It is bordered in front by a deep groove, $\frac{1}{8}$th of an inch from the external margin, which gradually unites with it half-way up the sides, which rapidly contract for $\frac{1}{4}$th of their length before reaching the posterior angle.

The Eyes are placed $\frac{3}{4}$ths of an inch apart, on either side of a median furrow, which, passing forward, divides into two semicircular arches, and is lost in a series of minute tuberculations. On either side of the median line are two small oblong tubercles, placed between and slightly in front of the eyes. The eyes themselves can hardly be said to be preserved in this specimen, but their position is clearly indicated.

Only two pairs of long appendages in *S. Powriei* are known. The basal joints of these were, no doubt, furnished with palpi, as in *Pterygotus*, *Eurypterus*, and *Slimonia*. They appear to have been eight-jointed, the first joints being broad and flat, precisely like that of *Stylonurus Logani;* the second, a short articulation not clearly seen; the third, about 1 inch in length, and having a keel down the centre; the fourth, 10 lines in length, also keeled; the fifth and sixth, 7 lines; the seventh and eighth, 6 lines each. The third and fourth joints seem to have been about 5 lines in width, and the others slightly narrower to the eighth, which terminates in a fine slender point, slightly incurved. The two pairs of limbs on either side appear to have been about equal both in length and breadth.

The Body-segments, twelve in number, increase gradually in breadth to the fourth, when they as gradually decrease to the eighth, whilst the four remaining segments rapidly decrease in breadth and increase in length.

Dimensions.—Thoracic segments:—First, 2 inches three lines broad, 3 lines long; second, 2 inches 5 lines broad, 5 lines long; third, 2 inches 5 lines broad, 5 lines long; fourth, $2\frac{1}{2}$ inches broad, $\frac{3}{4}$ths of an inch long; fifth, 2 inches 3 lines broad, 5 lines long; sixth, 2 inches 5 lines long; seventh (or first abdominal), 5 lines (about) long, 1 inch 7 lines broad (about); eighth (or second abdominal), 5 lines long, $1\frac{1}{2}$ inch broad; ninth (or third abdominal), 9 lines long, 17 lines broad; tenth (or fourth abdominal), 5 lines long, 14 lines broad; eleventh (or fifth abdominal), 6 lines long, 10 lines broad; twelfth (or sixth abdominal), 5 lines long, 9 lines broad, forming a semicircular curve into which the proximal end of the tail is inserted.

The Telson, or tail-spine, is 3 inches 10 lines in length, nearly 3 lines broad through its entire length, having a deep groove down its centre $\frac{1}{16}$th of an inch in width. Two zigzag lines of plicæ pass down from the head, on either side of the thoracic segments, about $\frac{3}{4}$ths of an inch from their lateral margins. These markings appear to be due to compression, and, as they are also noticeable in the Lanarkshire specimen, are probably lines along which muscular attachment within was strongest.

The Thoracic segments are slightly spinose along their posterior margins. *S. Powriei* had, probably, epimeral pieces to its abdominal segments; but being, as before stated, a cast, these pieces would not be shown attached, but remain upon the exterior slab, as is the case both in *Pterygotus Anglicus* in the Arbroath Museum, and *Stylonurus Scoticus* described herewith.

On Pl. XXI, fig. 2, is represented two detached parts of the long swimming appendages of *Stylonurus*, which, from their size, belonged to an individual larger than *S. Powriei* (fig. 1). The specimen shows that the joints were strongly keeled down the centre, and slightly serrated along the inner border.

Formation.—Pl. XXI, fig. 1, Old Red Sandstone; fig. 2, Upper Silurian.

Locality.—Fig. 1, Turin Hill range, Pitscandly, Forfarshire; fig. 2, Lesmahagow, Lanarkshire.

From the collection of James Powrie, Esq., F.G.S., Reswallie.

Species 2.—STYLONURUS MEGALOPS:—Salter, sp. 1859. Pl. XXI, fig. 3, 3 *a*.

EURYPTERUS MEGALOPS, *Salter*. Quart. Journ. Geol. Soc., 1859, vol. xv, p. 233, pl. x, figs. 9 and 10 (*not* figs. 11—14, which are referable to another species).
STYLONURUS — *H. Woodw*. Op. cit., 1865, vol. xxi, p. 486.

In a communication made by me to the Geological Society of London in June, 1865, I stated that, from an examination of *Eurypterus megalops*, Salter, from Ludlow, I was led to conclude that this was also a "*Stylonurus*."[1]

Under this name Mr. Salter had associated several detached body-segments, which, however, presented no character by which they might definitely be placed with the head-shield, upon which my conclusion was based.

"The head (writes Mr. Salter) in the largest specimens known is 1¼ inch wide (and this would give fully the length here assigned to the body [namely, 7 or 8 inches long]; it is wider than long, semicircular, granuloso-plicate, and with the hinder margin tuberculate.

"The great reniform eyes are nearly one third as long as the head, and (including the swollen base on which they are set, and the large circular eye-lobe which covers them) fully one third, measured from within the eye-lobes; they are about their own diameter apart, and placed much more than half-way, but not quite two thirds, up the head. The anterior margin of the head (carapace) is rounded, or very slightly angular, and margined all round the front."

Locality.—Base of Old Red Sandstone, Ludlow Railway.

Species 3.—STYLONURUS SYMONDSII:—Salter, sp. 1857. Pl. XXI, fig. 4.

EURYPTERUS SYMONDSII, *Salter*. Edin. New Phil. Journ., new series, 1857, vol. vi, p. 257.
— — *Salter*. In Murchison's Siluria, 3rd edition, 1859, p. 274, woodcut, Fossils (68).
— — *Salter*. Quart. Journ. Geol. Soc., 1859, vol. xv, p. 230, pl. x, fig. 1.
STYLONURUS — *H. Woodw*. Quart. Journ. Geol. Soc., 1865, vol. xxi, p. 486, pl. xiii, fig. 4.
— — *Murchison's* Siluria, 4th edition, 1867, p. 246, Fossils (69).

This very curious form, which was described by Mr. Salter, in 1859,[2] under the name of *Eurypterus Symondsii,* was obtained from the middle beds of the Old Red Sandstone ("Cornstones") of Rowlestone, south of the Hay, Brecknockshire. Only the carapace has as yet been obtained, but its square form, and the indications of the bases of the great sub-central eyes, leave me in no doubt in referring it to *Stylonurus.*

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[1] 'Quart. Journ. Geol. Soc.,' 1865, vol. xxi, p. 486.

[2] Id., 1859, vol. xv, p. 230.

It was named *Symondsii* in honour of the Rev. W. S. Symonds, F.G.S., of Pendock Rectory, near Tewkesbury, by whom it was first brought under Mr. Salter's notice, and by whose interest the original specimen is now preserved in the Museum of Practical Geology, Jermyn Street. A cast of the same may also be seen in the British Museum.

The specimen, of which we have only the exterior cast of a head, perfectly representing the surface, however, is impressed on a slab of brownish-gray micaceous grit, from the Upper Cornstones of Rowlestone, Brecknockshire, and was obtained by the Rev. Mr. Wenman. It is $2\frac{4}{10}$ inches long, and $2\frac{6}{10}$ inches broad at the wide anterior part, the greatest breadth being at the anterior third; the hinder edge is only 2 inches wide. The front margin is arched, and somewhat truncate in front, and gibbous at the sides, and from about halfway up the head it is double, or has an inner raised ridge 2 lines distant from the edge. This ridge is continuous all round with the somewhat elevated border of the sides, in such a way that the carapace appears complete, without the addition of the anterior border.

Exclusive of this border, which is concave, and somewhat bent downwards, the surface of the head is but very gently convex, and is covered, except along the posterior margin, by elevations and furrows, which give it a very rugged and lobed aspect. A deep Y-shaped vertical furrow, forked upwards at an angle of 30°, divides the space between the eyes, and occupies the middle third of the head;[1] the space between the branches is very convex.

A shallower depression takes its origin above the eyes, and radiates outward to the front margin; a pair of shorter furrows run obliquely outwards behind those organs; another deep oblique depression occurs further back, at half an inch from the hinder border, and outside it a strong triangular lobe is marked out, partly by this furrow and partly by a submarginal one, which occupies about one third the length of the head. Between these strong lateral lobes, and on the same level, a central tubercle, flanked by two depressions, occurs immediately behind the deep Y-shaped furrow first noticed. Lastly, there is a short and shallow pair of furrows in the central front portion of the head.

The posterior border is quite plain for a breadth of half an inch, and free from ridges or furrows of any kind. The posterior angles are slightly obtuse and not at all produced, the hinder edge is sinuous, and without the raised border which runs round all the rest of the margin. The eyes are large, rounded, and circumscribed by a sunken space; they are placed more than half-way up the head, and as wide apart as they are distant from the outer margin. As they are abraded in this unique specimen, their shape and convexity cannot be ascertained; they appear to have been large and rounded.

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[1] In *E. Scouleri* there is a ridge, forked *downwards,* between the eyes.

In a communication made by me to the Geological Society in June, 1865,[1] I pointed out that there was now good evidence, from the specimens of other species, discovered, since Mr. Salter described it, by Mr. James Powrie, F.G.S., in Forfarshire, and Mr. Robert Slimon, in Lanarkshire, that the remarkable crustacean carapace, referred by Mr. Salter to *Eurypterus*, was a true *Stylonurus*, agreeing most closely with *S. Logani* and *S. Powriei* in form. I accordingly referred it to that genus in the paper above quoted, and I see no reason for doubting the correctness of its allocation.

Formation and Locality.—Old Red Sandstone, Rowlestone, Brecknockshire. No other specimen has since been obtained.

Species 4.—STYLONURUS ENSIFORMIS :—H. Woodw. Pl. XXI, fig. 5.

STYLONURUS ENSIFORMIS, *H. Woodw.* Geol. Mag., 1864, vol. i, p. 198, Woodcut, p. 199.

A tail-spine of *Stylonurus*, nearly 4 inches long (probably longer when perfect), $\frac{3}{4}$ths of an inch in width, and deeply channelled through its entire length, from $\frac{3}{8}$ths at its widest part, and $\frac{1}{8}$th of an inch at its extremity, was found in the Old Red Sandstone at one of the Turin Hill quarries in Forfarshire.

This spine is so peculiar in its form, and so distinct from any other specimen as yet met with, that I have ventured to name it *Stylonurus ensiformis.* The specimen is in the collection of Mr. James Powrie, F.G.S., of Reswallie.

Formation and Locality.—Old Red Sandstone, Turin Hill Quarries, Forfarshire.

Species 5.—STYLONURUS SCOTICUS :—H. Woodw. Pls. XXII and XXIII.

STYLONURUS SCOTICUS, *H. Woodw.* Brit. Assoc. Reports, Bath, 1864, p. 73.
— — *H. Woodw.* Quart. Journ. Geol. Soc., 1865, vol. xxi, p. 484, pl. xiii, figs. 2 and 3.

Although not so large as *Pterygotus Anglicus*, this species is, perhaps, the most remarkable of all the Palæozoic Crustacea. It was found in an Old Red Sandstone quarry in Montroman Muir, near the Forfar and Montrose Pike, by James Powrie, Esq., of Reswallie.

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[1] 'Quart. Journ. Geol. Soc.,' vol. xxi, p. 486.

It is represented by a separate carapace (Pl. XXII), the relievo side of which is in Lady Kinnaird's cabinet, and the intaglio in the British Museum collection, and by an almost entire example (Pl. XXIII) which Mr. Powrie has been so fortunate as to obtain, and which is preserved in his museum at Reswallie. The latter is lying on a slab of Old Red Sandstone, at full length, with its dorsal aspect exposed, and the last five body-segments detached entire, so as to show both the ventral and the dorsal surfaces. The impression of the upper surface of the same on a separate slab exhibits in the most perfect manner the epimeral portions of each of the last four segments, and also the remarkable spatulate telson, 9 inches in length.

The entire specimen is 3 feet 4 inches in length. The margin of the carapace is much injured, but fortunately the separate carapace is well-nigh perfect, so that we are at no loss to ascertain its contour. The posterior margin of the head is at its narrowest point 9½ inches in breadth and (about) 8 inches in length.

There is an oblong median ridge in the centre of the carapace, terminating in a smooth rounded prominence 3 inches from the posterior margin, and extending forward about 2 inches. On either side of this central line are two smaller oblong prominences, rising more in advance of the central ridge (4¼ inches from the posterior margin, and about ¾ths of an inch in length), broader in front than behind, and curving away from the median line, from which they are distant ½ an inch on the other side. The central ridge and lateral prominences are carried forward in a V-shaped elevation, which spreads out laterally as it advances, the whole of the front and antero-lateral portion being coarsely tuberculated, a single irregular row running down the median ridge.

The Eyes are situated parallel to the median ridge, and take their rise exactly 1 inch on either side. They are almost identical in form with those of *Phacops* and *Asaphus* among the Trilobites, being arranged in a semilunar or horseshoe shape around a raised prominence. The cornea of the eye measures 22 lines, and is disposed outwards and forwards, the centre being directed towards the latero-anterior angles. The eyes are elevated about 5 lines above the surface of the carapace; probably they may have been even higher, but are somewhat compressed.

Very minute scale-like markings are seen on the lateral and posterior margins of the carapace and body-segments.

The margin of the head is double around the frontal and latero-anterior portion, as in *S. Powriei* and *S. Logani*, &c.

Thoracic Segments.—The first segment is $1\frac{1}{16}$ of an inch in length and 10 inches in breadth; the lateral portion is rounded and curved upwards; the surface is minutely scale-marked.

The second segment is 17 lines in length and 10 inches in breadth. A series of long tubercles borders the posterior margin, and the surface is covered with minute scale-markings. The lateral portion is rounded and slightly expanded.

The third segment is 2 inches wide and 10½ broad. Three principal prominent tubercles and several smaller ones mark the posterior margin, pointing backwards.

The epimeral portion of all the thoracic segments is widely rounded, and a broad margin of each segment overlaps the succeeding one.

The fourth segment exposes 1 inch and 10 lines of its length.

The tubercles upon this and the third segment are the most strongly marked of any. It is 11 inches in breadth. The fifth segment (thoracic) is 1¾ inch in length, and 9 inches broad. The sixth segment is 19 lines in length and (about) 8 inches in breadth. The seventh (or first abdominal) is 2 inches in length and from 5 to 6 inches in breadth. (Here the specimen is fractured across, and the margins of this segment are wanting.) Each of the abdominal segments has large epimeral pieces, which have been well preserved upon the surface of the overlying slab.

The eighth (or second abdominal) is 14 lines in length and 5 inches in breadth, including the epimeral portion, which is clearly shown. The ninth (or third abdominal) is 2½ inches long and 4¾ in breadth. The tenth (or fourth abdominal) is 2⅛ inches in length and 4½ inches broad, including the epimeral portion. The eleventh (or fifth abdominal) is 2¾ inches long and 3 inches 10 lines in breadth, including the epimeral portion. The twelfth (or sixth abdominal) is 2¼ inches in length and 3¾ inches in width. From this segment two elongated epimeral pieces are developed, measuring 4½ inches in length by about 5 lines in width, and terminating in a broad rounded point.

The Telson (9¼ inches in length) is somewhat broad at the point of attachment, and becomes slightly narrower in the first quarter, gradually widening to 1½ inch.

The central depression is ¾ inch in width. The termination is rounded, and the border does not appear to have been ornamented. Of the appendages, there remains only the joint of a swimming-limb attached to the left margin of the carapace, measuring 4 inches in length by 2 in breadth, and having a row of tubercles upon the centre.

In a letter dated 9th February, 1865, Mr. Powrie wrote to me as follows:

" Mr. Salter has expressed his conviction that *Stylonurus Powriei* and *S. Scoticus* are specifically the same—the larger one a full-grown male, and the smaller a young female, the longer and narrower body, shorter tail, and epimeral appendages being all characteristics of the male; in other respects the resemblance is most marked."

Were we to accept this opinion, that *S. Powriei* and *S. Scoticus* are identical, then the method of determining the sexes in the British and American species of *Eurypterus*, *Pterygotus*, and *Slimonia*, hitherto adopted, namely, by the two forms of thoracic plates, must be abandoned. Moreover, if we are to be guided by more general characters than those of the sexual plates, we must expect the antennæ to be modified in the male, as in the recent *Limulus;* in which case the two or three forms of plates in *Slimonia acuminata* would indicate two or three species of females, while the several forms in *Pterygotus bilobus* would probably indicate the males with their chelate antennæ. But to establish this position, most palæontologists would require evidence as conclusive as that obtained by Mr. Binney in the case of *Stigmaria* and *Sigillaria*.[1]

Formation and Locality.—Old Red Sandstone, Forfar.

Species 6.—STYLONURUS LOGANI:—H. Woodward. Pl. XXIV, fig. 1.

STYLONURUS, *Page.* Brit. Assoc. Rep. Glasgow, 1855, p. 89.
— SPINIPES, *Page.* Advanced Text-Book, 2nd edition, 1859, p. 181, fig. 1 (*no description*).
— LOGANI, *H. Woodward.* Geol. Mag., 1864, vol. i, p. 197, pl. x, fig. 1.

Since Mr. Page figured *Stylonurus Powriei* in 1856, then the only species known, much better specimens have been found, not only by Mr. Powrie, of Reswallie, in Forfarshire, but also by Mr. Robert Slimon, of Lesmahago, in Lanarkshire. A specimen of another species of this genus, from the last-named locality, furnishes us with most valuable details as to the minute structure of this remarkable generic form.

Only one specimen of this species from Lesmahagow, Lanarkshire, is known, the intaglio half of which is in the Museum of Practical Geology, Jermyn Street, and the relievo half in the collection of Mr. James Powrie, of Reswallie. It is from the former half that our present figure is taken[2] (Pl. XXIV, fig. 1).

The specimen exhibits the carapace and the body-rings as far as the tenth segment united, and one of the long slender swimming-feet *in sitû* on the left side, whilst on the right are seen the bases and portions of two other long appendages. Lying upon the slab, in various positions around the head, are four spiny eight-jointed palpi, or foot-jaws, one of which still retains its attachment to the carapace, although twisted and bent from its natural position.

Upon referring to the figure of *Stylonurus Powriei* in Page's 'Advanced Text-book' (3rd edit., p. 190, fig. 1), it will be seen that it has *two pairs* of long slender swimming-feet upon either side of the head. In the species here figured, from Logan Water, there is also evidence of a second pair of long limbs, making, with the spiny palpi, four pairs of appendages; the fifth and absent pair being, no doubt, the antennæ, which, as in *Slimonia* and in *Eurypterus*, were probably much smaller (*ante*, p. 109, Fig. 31, *et infra*, p. 142, Fig. 44). The form of the carapace in *Stylonurus* is well marked, and very different from any other genus in this singular family.

In the Logan Water shales, although the finest and most delicate markings are often preserved, yet the specimens are so compressed as to give scarcely any idea of their original contour, except by comparison with those from the Old Red Sandstone of Forfarshire and elsewhere.

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[1] See Dr. Hooker's Memoir on "Vegetation of the Carboniferous Period;" 'Mem. Geol. Surv.,' 1848, 8vo, vol. ii, part ii, pp. 417, 432, &c.

[2] We figured Mr. Powrie's specimen in the 'Geological Magazine,' 1864, vol. i, pl. x, fig. 1.

The Eyes are situated upon the surface of the carapace, somewhat near the anterior angles. They were reniform, and raised upon round prominent bosses, but these are now squeezed flat to the surface of the head.

The Carapace is quadrate, with the anterior angles rounded; the sides present a slightly waving outline, contracting towards the posterior angles. The margin is double, having an inner ridge, which circumvents the sides and front and terminates in a rounded elevation at the posterior angles. An inner border-line also passes up each side and around the front of each eye, reminding us of the cheek-sutures in the Trilobites.

No sculpturing is noticeable upon the surface of the carapace, but (as is the case with all the Logan Water specimens) impressions of portions of the organs are seen, the position of which is beneath the surface of the head.

The basal joints of several of the palpi are visible; and, underlying the 1st and 2nd thoracic segments, may be discerned the median appendage of the thoracic plate.

The Body is extremely slender, as compared with *Pterygotus*, and the segments in this species (as in *St. Powriei*) had very small epimeral portions. The 11th and 12th segments, which are not preserved, were doubtless still narrower; and the telson was probably a long styliform appendage, as in *St. Powriei.*

Dimensions of *Swimming-foot*:—Basal joint, 6 lines in length and 5 broad; 2nd joint, 2 lines long, 4 broad; 3rd, 1 inch long, 2 lines broad; 4th, 10 lines long, 2 lines broad; 5th and 6th, each 8 lines long and 2 lines broad; 7th, 6 lines long, 1 line broad; 8th, 5 lines long, 1 line wide, terminating in a fine point.

Carapace:—Greatest anterior breadth, 1 inch 3 lines; greatest length, 1 inch 2 lines; width between the eyes, 5 lines; breadth of inner raised margin, 1 line.

Thoracic segments:—1st segment, 2 lines long and 1 inch and 1 line wide; 2nd and 3rd, 3 lines long and 1 inch wide; 4th, 4 lines long and 1 inch 1 line wide; 5th, 3 lines long by 1 inch wide; 6th, 2 lines long and 11 lines wide. The posterior margin of each segment is ornamented by a row of minute spines along the border.

Abdominal segments:—7th segment, 2 lines long by 10 lines wide; 8th, 3 lines long by 9 lines wide; 9th, 3 lines long by 8 lines wide; 10th, 3 lines long;—here the specimen is broken, and the 11th and 12th segments and telson are wanting.

The form of the carapace and the position of the eyes are two very well-marked features in this genus; these, and the two pairs of long slender oar-like feet, sufficiently separate them from the rest of the family, but even the long tail-spine is peculiar.

From the extreme rarity of its occurrence in a formation where other genera are so numerously represented, I am strongly inclined to believe this form to have been a *larval* condition probably of some other genus of the same group.

I have named it after my friend Sir William Logan, F.R.S., the late Director of the

Geological Survey of Canada, whose great services to geological science, as well as his kindly disposition to all, will long cause him to be remembered and esteemed.

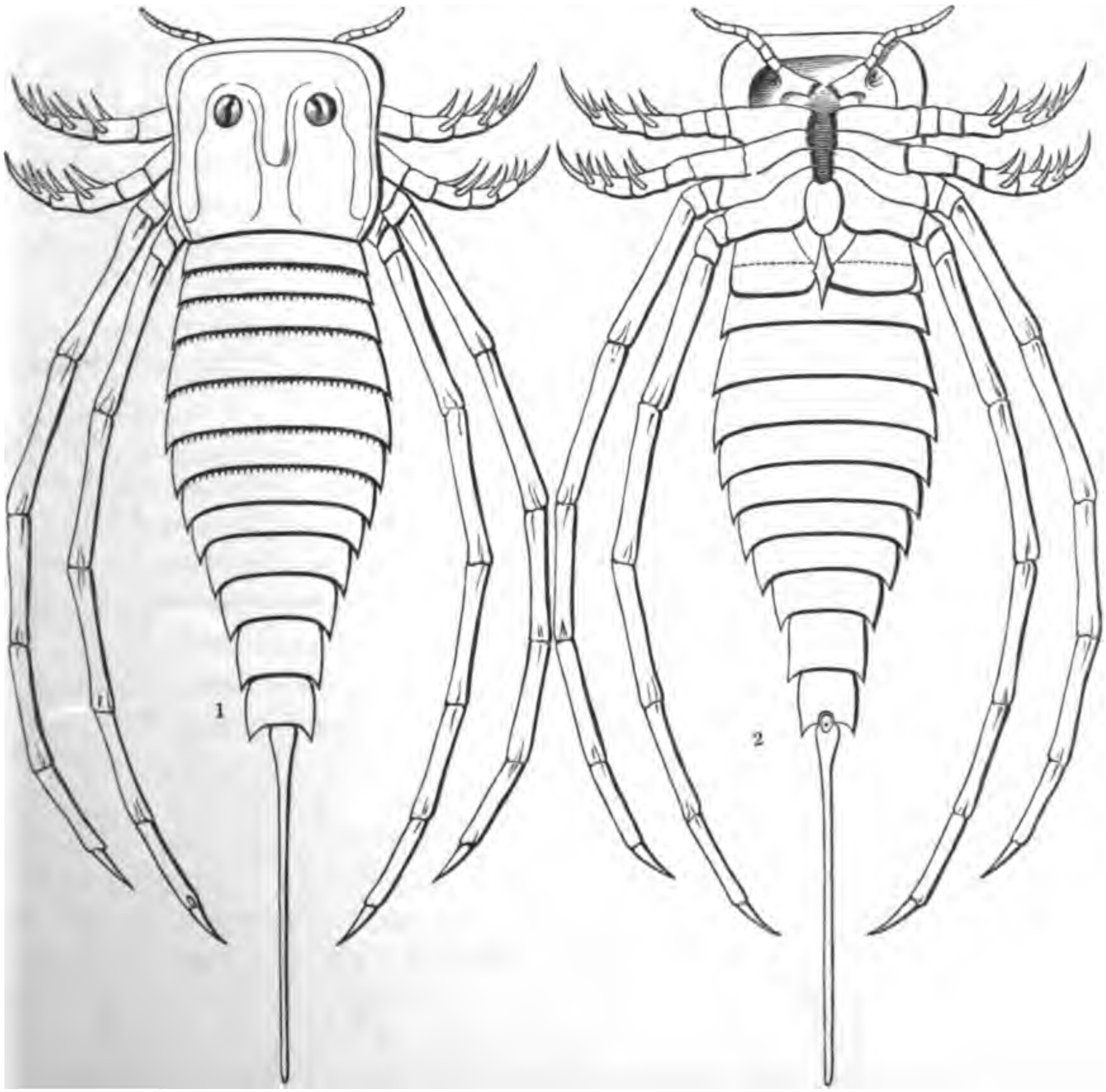

Fig. 39.—*Stylonurus Logani*, H. Woodward (restored).
About natural size. From the Upper Silurian, Lesmahagow, Lanarkshire.
1. Dorsal view. 2. Ventral aspect.
(Only the 10 anterior body-segments are preserved; the hinder part and the telson are added from the evidence afforded by the specimen of *Stylonurus Powriei* from the Devonian. See Pl. XXI, fig. 1.)

Formation.—Upper Silurian.

Locality.—Logan Water, Lesmahagow, Lanarkshire.

The original specimens are in the collection of James Powrie, Esq., F.G.S., of Reswallie, Forfar, and in the Museum of Practical Geology, Jermyn Street.

Genus 4.—Eurypterus, *Dekay*, 1825.

The first notice of the discovery of *Eurypterus* was made in America in 1825 by Dr. J. E. Dekay, who described and figured the only species then known, the *Eurypterus remipes*, and referred it to the class Crustacea, and to the order *Branchiopoda*.

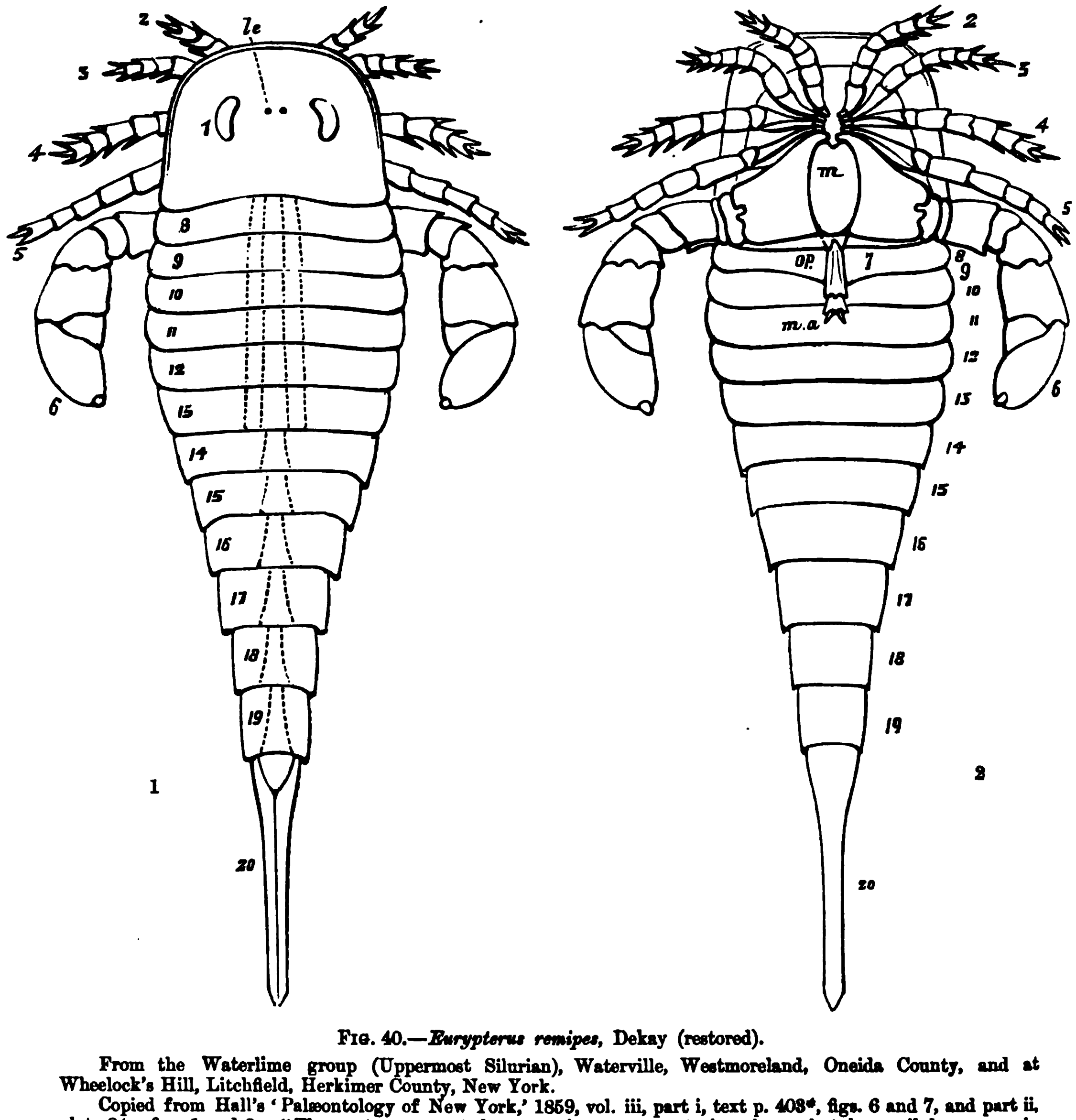

Fig. 40.—*Eurypterus remipes*, Dekay (restored).

From the Waterlime group (Uppermost Silurian), Waterville, Westmoreland, Oneida County, and at Wheelock's Hill, Litchfield, Herkimer County, New York.

Copied from Hall's 'Palæontology of New York,' 1859, vol. iii, part i, text p. 403*, figs. 6 and 7, and part ii, plate 84A, figs. 1 and 2. "The parts represented are not in any respects imaginary, but have all been seen in different individuals or parts of individuals, and are known to have the relations here expressed." (Explanation of plate 84A by Prof. James Hall.)

1. Dorsal view. 2. Ventral aspect.

The remains of a British species of *Eurypterus*, which probably measured nearly two feet in length, were discovered in the Freshwater Limestone of Carboniferous age, at Burdie House, near Edinburgh, and recorded by Dr. John Scouler, of Glasgow, in 'Cheek's Edinburgh Journal' (vol. iii), 1831, under the generic name of *Eidothea*.

In 1836, Dr. S. Hibbert figured four specimens of this Burdie House Crustacean, and referred them to *Eurypterus*, under the name of *E. Scouleri*.[1]

Dr. Harlan, Mr. Conrad, Mr. Vanuxem, and Prof. James Hall, in America; Fischer de Waldheim, Edward von Eichwald, and Dr. J. Nieszkowski, in Russia; Prof. Reuss, Dr. Jordan, and H. von Meyer, in Germany; and Mr. J. W. Salter, in England, have all contributed to the bibliography of this genus.

Both the Russian and American species of *Eurypterus* are well preserved, and have been carefully figured.

But the most instructive and elaborate description and figures of this genus are to be found in the 'Palæontology of New York' (vol. iii, 1859), by Prof. James Hall, of Albany.

The figures on the preceding page are copied from his work, and convey the clearest idea of the details of the organs and form of the body-segments in this genus which have yet been produced. They will prove of the greatest service in elucidating the less perfect and often very fragmentary remains which occur in our own rocks.

As elsewhere shown in the Tables of the Geographical and Geological Distribution of the Merostomata (see Part I, pp. 11—19), there is in this, as in all other fossil genera, the same relative distribution in time and space.

Thus we find *Eurypterus* represented in time from the Lower Ludlow (*U. Silurian*) to the Lower Carboniferous—the greatest longevity attained by any of the EURYPTERIDA; whilst in space they extend from the United States and Canada to England, and so on to Oesel and Gotland, Poland, Russia, Bohemia, and Rhenish Prussia.

About 23 species are known belonging to this genus, 17 of which occur in the Upper Silurian, the rest are found in the Devonian and Carboniferous rocks (see p. 19).

Species 1.—EURYPTERUS SCOULERI:—Hibbert, 1836. Pls. XXV—XXVII.

EIDOTHEA, *Scouler*, 1831. Cheek's Edinb. Journ. of Nat. and Geogr. Sc., new ser., No. vi, June, 1831, pl. x, p. 352.

EURYPTERUS SCOULERI, *Hibbert*. Trans. Roy. Soc. Edinb., 1836, vol. xiii, part i, p. 280, pl. xii.

— — *Ib.* Salter, Quart. Journ. Geol. Soc., 1863, vol. xix, p. 82.

— — *Ib.* Page's Advanced Text-Book of Geology, 1859, 2nd edition, p. 189 (with a woodcut).

The Council of the Andersonian Institution have kindly granted me permission to examine and figure the fine head of *Eurypterus Scouleri*, which forms the subject of our Pl. XXVII. This is the original specimen figured in 'Cheek's Edinburgh Journal,' by Dr. John Scouler, F.L.S., in June, 1831, under the name of *Eidothea*.

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[1] 'Trans. Roy. Soc. Edinburgh,' vol. xiii, p. 280, pl. xii.

For the opportunity to figure the other carapace and conjoined posterior body-segments of this remarkable Crustacean, forming the subjects of Pls. XXV and XXVI of this Monograph (and which were with the preceding specimen all figured by Dr. Hibbert in the 'Trans. Roy. Soc. Edinburgh,' 1836, vol. xiii, pl. 12), I am indebted to the kindness of my friend James Powrie, Esq., F.G.S., of Reswallie, Forfarshire.

Of the first of these specimens Mr. Salter writes as follows :[1]—" The large carapace is all but perfect (a portion of the right side only being absent), and in its natural condition uncompressed; so that the great convexity of the form is manifest. The carapace and the two front body-rings (preserved so as to show both their dorsal and ventral surfaces) are retained in this specimen, attached to one another; and, bent upward beneath it, is a large fragment of a swimming-foot, consisting of the first four joints, all imperfect.

" The dimensions are as follows :—Carapace, forming more than a quarter of a sphere, [6][2] inches long by fully [8] broad, and the convexity such as to follow the shape of the body-rings, which are each [6½ inches] broad and [¾ inch] deep from back to front. The greatest convexity is in the region behind the eyes, which are placed, not quite halfway up the head, near together, only an inch and a quarter apart. They are divided from each other by a pair of inflated triangular lobes, with a small central process lying in the deep hollow between them. This central prominence, the round approximate eyes, together with the rough, hirsute, spinous character of the convex region behind the eyes, give the whole head much the appearance of a deformed human countenance.

" The outline of the carapace is about two thirds of a circle, the short, broad, spinous ears being curved inwards, not outwards; and the posterior edge is only gently arched. A very distinct depression indents the front, but does not affect the actual anterior margin. The round prominent eyes are also set in depressions, which run from them in a curved line to the inner margin of the broad posterior spines on each side, and thus enclose the convex, semicircular space which, lying behind the region of the eyes, is covered with thick-set spinous squamæ. Another deep triangular indentation lies between two thick lobes, diverging backward, which separate the eyes; and, as these lobes are much swollen, the depression is really greater than any of the others. In the midst of it lies a short, triangular, prominent mass, broken in our specimen. Above, in front of this depression, is a slight boss (which would very probably be the place of the minute stemmata, were they preserved); but there are no wrinkles nor elevations of any kind in front of the eyes. The whole surface is evenly convex, divided by the semicircular furrows from the rugose portion behind the eyes, as above mentioned. The margin is narrow,

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[1] 'Quart. Journ. Geol. Soc.,' 1863, vol. xix, p. 82.

[2] The specimen having been remeasured, the numerals within the brackets are the correct dimensions. —H. W.

thickened, and raised all round. The ornament of the surface is minute in front, and consists of small prominent tubercles, with minute granules between them; further down the sides the tubercles become triangular squamæ, with others interspersed; and these squamæ become larger and larger towards the ears (with raised borders, and generally a strong central tubercle), and attain their largest size on the posterior area, where they are also narrower and more pointed, as well as stronger, than elsewhere. On the extreme hinder border they become linear ridges, and in this form they also occur on the free edges of the body-segments. The crust is not thick; and the squamæ, except in the largest, appear to be more convex and prominent beneath the crust than above it, so as to indent the cast. This is particularly the case with the smaller squamæ, which are so concave above as to be truly convex below; the margin shows this conspicuously, and wherever the surface has been abraded or weathered, the hollows are much deepened and exaggerated.

"The body-rings have a great convexity, as above stated; the two anterior rings are very short, not more than [$\frac{3}{4}$ths] of an inch long even in this large specimen. On the under side they expand into the broad sternal flaps so characteristic of this family of Crustacea. One of the swimming-feet is [partially] preserved. The basal joint is either very small, compared with that of *Pterygotus*, or is imperfect. The shape of the other three is not well defined; but they are evidently thick, carinate at the edges, and have the usual triangular or wedge-like shape alternately in the lower joints."

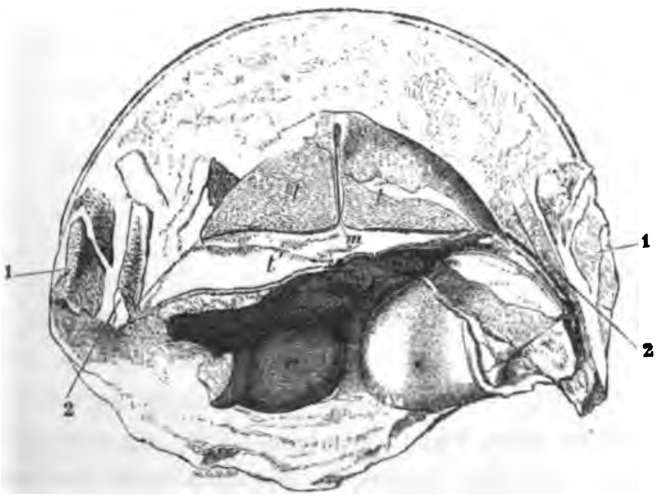

FIG. 41.—Under side of head of *Eurypterus Scouleri*, Hibbert.
From specimen in Mr. James Powrie's collection.

In Dr. Hibbert's description of *Eurypterus Scouleri*, he says ('Trans. Royal Soc. Edinb.,' vol. xiii, p. 281):—"The *Eurypterus Scouleri* is to be distinguished from other species by the prolonged eminences intervening between the eyes, which, at their apex, form an angle wherein appears a central tubercle; also by the small, acutely angular protuberances, like spines, which are diffused over the surface of the head beneath the eyes. The characters of the feet cannot be given, as no vestiges of them, except very slight ones, have turned up. In truth, there is no known species with which it can be confounded, nor any approaching it in size."

Of the other specimens of *E. Scouleri* from Mr. Powrie's collection, the head (Pl. XXV) is principally important on account of its under side (Pl. XXV, fig. 1*c*, and Woodcut, Fig. 41), which, after careful and patient development, has revealed the bases of the great swimming-feet or maxillipeds (*e*, *e*), and a large elliptical plate (*t*, *t*), which I can only interpret as the thoracic plate forced in and displaced by pressure, so as to occupy its present position under the carapace. A second and inner plate, marked *t'*, underlies this opercular plate; there are also remains of two pairs of endognathary palpi (1 and 2) on either side. This assumed thoracic plate (?) is strongly arched, and is divided down the centre by a suture (*m*), extending nearly to its upper and anterior border.

A portion of one of the ectognaths is preserved upon the under side of the fine head from the Andersonian University collection[1] (Pl. XXVII) already described, but not in a sufficiently perfect state to be worth figuring here.

Body-segments.—We have evidence of ten body-segments belonging to this species, two of which, the most anterior, are attached to the large head figured on Pl. XXVII; the remaining eight are the most posterior of the body-rings, and are from Mr. James Powrie's collection.

These last named (Pl. XXVI) being united in series, give a very excellent idea of the peculiar short robust form of the body in *E. Scouleri* as compared with the other species of *Eurypteridæ*. The segments are very short in proportion to their breadth and thickness, and are folded in along each margin, so as to form a most powerful series of articular surfaces to the body-rings, capable of offering enormous resistance to external force.

The subjoined Woodcut (Fig. 42) may serve to illustrate this structure, which presents a stronger form of body-joint than that of any modern Crustacean with which I am acquainted, there being no interspace between the body-rings protected by connecting membrane, as in many Macrouran Decapods, but the solid somites are each furnished with a broad infolded margin (measuring, in the second segment from the head, three fourths of an inch in width), which is convex along the anterior border of each ring and concave along the posterior edge, while the lateral angles are compressed into a ball in front, and enlarged into a socket behind, so as to complete the powerful hinge of this armour-plated body-covering.

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[1] It is possible that some further light might be afforded as to the appendages of this very remarkable species, by attempting to develope the underside of this last-named specimen, but the tough and concretionary nature of the matrix, which yields most unwillingly under the chisel-point, renders the task of removing it not only very difficult, but also somewhat dangerous to the specimen itself, which would be very apt to shatter from the repeated blows required. I have therefore thought it more prudent to desist.

The remains referred to give evidence of two individuals differing considerably in size; the head-shield of the larger specimen (Pl. XXVII) measuring 8 inches in breadth and 6 inches in length along the convex dorsal surface of the shield, whilst the smaller, (Pl. XXV) measures 7 inches in breadth and 5½ inches in length.

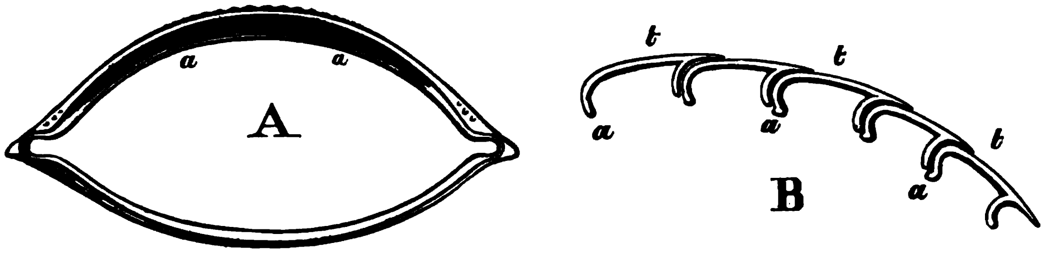

Fig. 42.—(A) Diagram of articular surface of posterior border of one of the body-rings of *Eurypterus Scouleri*. (B) Diagram of longitudinal section of body-rings of same, showing the mode of articulation of the segments; *t*, *t*, tergal pieces; *a*, *a*, infolded articular borders.

The detached series of posterior segments figured on Pl. XXVI may have belonged to an individual equal in size to that represented by the lesser head-shield. The posterior segments show a considerable increase in length, as compared with the two most anterior (thoracic) rings, but they have also diminished considerably in breadth.

These two anterior body-rings (attached to the head, see Pl. XXVII) are ornamented with a single row of narrow, acute, well-defined, spine-like squamæ, very like those on the posterior border of the head-shield. They are each 6½ inches in breadth along the dorsal surface and ¾ths of an inch in length.

The posterior free margin of the series of abdominal somites (Pl. XXVI) is ornamented on its dorsal border with a series of blunt, rounded, equidistant spines, and the surface itself is covered with squamæ (Pl. XXVI, figs. 1 and 3), whilst the ventral border of the larger segments is roundly dentated (figs. 2 and 4), and that of the penultimate segment is more acutely so (fig. 5). The ventral surface is not covered with squamæ, but is finely punctate, reminding one of the structure of the carapace in many Brachyurous Crustaceans.

The circumference of the xiith segment is 10½ inches, and the breadth of its dorsal surface 5¼ inches. That of the xviith is 8½ inches, and the breadth of its dorsal surface 4 inches. Girth of the penultimate segment 5 inches, breadth 2½ inches. The length of the 8 posterior segments, measured down the dorsal line, is 6½ inches.

Guided by the two thoracic segments (Pl. XXVII), and by the series of united abdominal segments seen in Mr. Powrie's specimen (Pl. XXVI), I have prepared a drawing of the entire body of *E. Scouleri* to the scale of the larger head-shield figured on our Pl. XXVII, from which I estimate the entire body to have been 22 inches in length, divided as follows:

Head, 5½ inches in length.
Six anterior (thoracic) body-segments, 4½ inches.
Six posterior (abdominal) do. 6 „
Caudal spine (?) . . . 6 „

The caudal spine and appendages of this species at present remain unknown, but as all the other species of Eurypterida possessed a more or less ensiform tail-spine, we may pretty safely conclude that *E. Scouleri* was furnished with a similar organ.

Although there is, at present, no absolute necessity to establish a distinct genus for *E. Scouleri*, not being as yet fully acquainted with all the details of its structure, nevertheless I think it right to point out that this species presents many anomalies and considerable divergence from the type-form of *E. remipes* (Fig. 40, p. 132). In the curious form of the eyes, elevated above the carapace, upon a round base or peduncle, and in the singular bifurcating median ridges or crests between the eyes, we are reminded of *Stylonurus Scoticus;* but the rounded, almost hemispherical, head-shield finds its analogue alone in the carapace of the modern *Limulus*. In point of size, also, *E. Scouleri* claims a place among the largest of the Merostomata. In geological position this species is one of the latest, if not the very last, representative of the Eurypterida in the Palæozoic rocks.

Formation.—Lower Carboniferous Freshwater Limestone.
Locality.—Burdie House, near Edinburgh.

The associated fossils with *E. Scouleri* at Burdie House are—

Reptilia:—*Pholidogaster pisciformis*, Huxley.

Fishes:—*Eurynotus crenatus*, Ag.
Uronemus lobatus, Ag.
Rhizodus Hibberti, Ag.
Megalichthys Hibberti, Ag.
Gyracanthus tuberculatus, Ag.
„ *formosus*, Ag.
Palæoniscus Robisoni, Hib.
„ *striolatus*, Ag.

Together with *Sphenopteris affinis*, Lindl., Stems, Leaves, and Fruits of *Lepidodendron*, *Calamites*, and many other plants.

The beds are also exceedingly rich in Entomostraca.

Original specimens in the collection of James Powrie, Esq., F.G.S., Reswallie, Forfar, and of the Andersonian University Museum, Glasgow.

A restoration of this singular Palæozoic Crustacean, based upon the specimens figured in Pls. XXVI and XXVII, is attempted on the opposite page. Only fragments of the appendages are at present known.

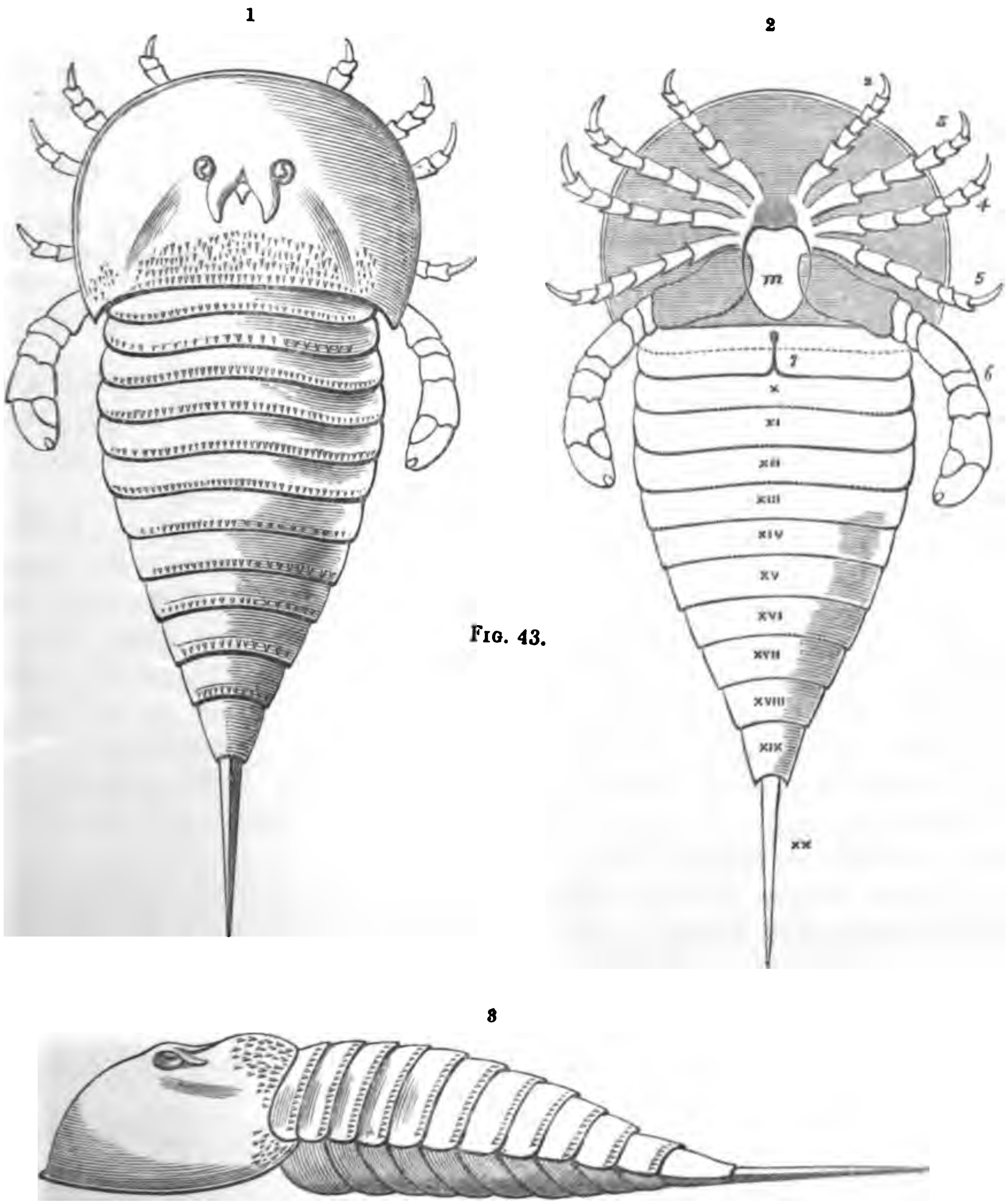

Fig. 43.—*Eurypterus Scouleri*, Hibbert (restored).
About one fourth the natural size. From the Freshwater Limestone of Carboniferous Coal-measures, Burdie House, near Edinburgh.
1. Dorsal view. 2. Ventral aspect. 3. Side view.
The appendages are restored after the American species figured by Prof. Hall; at present the evidence afforded by English specimens of this genus are too fragmentary to be of much assistance.
The figures and numerals correspond with those in the restored figures of *Pterygotus* given on Pl. VIII, Part I, of this Monograph. See also note on p. 107, Part III.

Species 2.—EURYPTERUS LANCEOLATUS:—Salter. Pl. XXVIII, figs. 1, 2, 3.

HIMANTOPTERUS LANCEOLATUS, *Salter*. Quart. Journ. Geol. Soc., 1856, vol. xii, p. 32,
— woodcut, p. 28, fig. 5.
EURYPTERUS LANCEOLATUS, *Salter*. Mem. Geol. Surv., 1859, Mon. I, p. 65, pl. i, fig. 17.
— — *H. Woodward*. Geol. Mag., 1864, vol. i, pl. v, figs. 7, 8, and 9, p. 107.
— CHARTARIUS, *Salter*. Quart. Journ. Geol. Soc., 1859, vol. xv, p. 234.

This species was first noticed by Mr. J. W. Salter, under the generic appellation of *Himantopterus*, in a paper on some new Crustacea from the Uppermost Silurian Rocks of Lesmahagow, Lanarkshire, read before the Geological Society, November 21st, 1855.

At that time only the penultimate segment and the telson were known.

In 1859, Mr. Salter described eight species of *Eurypterus*, from the Upper Ludlow Rocks and the Old Red Sandstone, but he did not refer to *E. lanceolatus* in that paper.

Of the seven species there noticed for the first time, two, namely, *E. Symondsii*, and *E. megalops*, are now referred to *Stylonurus* (see ante, p. 124). Four others, viz.: *E. pygmæus*, *E. acuminatus*, *E. linearis*, *E. abbreviatus*, are still retained, whilst the seventh and last, named by the author *E. chartarius*, Mr. Salter some years ago, in reply to my inquiries concerning it, kindly informed me that he no longer considered to be a distinct species, but only an obscure specimen of *E. lanceolatus*. In this opinion I must acquiesce, as I have not been able to see the original specimen referred to in Mr. Salter's description (but not figured by him).

In the 'Memoirs of the Geological Survey' (1859), Monograph I, "On the genus *Pterygotus*," by Prof. Huxley and Mr. J. W. Salter, the entire body, with the swimming-feet, of a specimen of *Eurypterus lanceolatus* is described and figured (p. 65, pl. i, fig. 17); but, owing to the imperfect state in which the fossil is preserved, it was impossible to give a very detailed description of the separate parts, or even to be quite certain (except from the spine-like form of the caudal joint) that it was a true *Eurypterus;* it was the only specimen then known.

Mr. Slimon, of Lesmahagow, from whom all the Lanarkshire specimens of *Eurypterida* have been obtained, has laboured on incessantly since the discovery of the beds in 1851, and has increased our knowledge of these remarkable Crustaceans by more perfect specimens from year to year.

The British Museum lately acquired, among other specimens, the impression and counterpart of a very beautiful and nearly perfect example of *Eurypterus lanceolatus* from this locality. The specimen measures only 4 inches in length, and barely 1 inch across the fourth and widest thoracic segment. (See Pl. XXVIII, fig. 2.)

In the form of the joints of the swimming-feet, in the number of the body-segments, the shape of the telson and thoracic plate, it closely agrees with the American, and, so far as is known, with the Russian, species of *Eurypterus;* but the carapace is more oblong-ovate vertically, whilst that of the American species is much broader and shorter in proportion. The eyes in *E. lanceolatus* are placed much nearer to the margin of the carapace than in other species; the swimming-feet are longer and narrower, and the thoracic plate seems deeper in proportion to its width, compared with Prof. James Hall's figures of the American *E. remipes* (see ante, Fig. 40, p. 132), &c. This is *not absolutely* the case, however; but is, I believe, due in a great degree to the fact that in Prof. Hall's restoration the broad basal joints of the swimming-feet and part of the post-oral plate are placed considerably beyond the posterior margin of the carapace, so that they overlap nearly one half of the thoracic plate, a position which seems highly improbable, if not absolutely impossible, for them to have occupied during life, and in which they never occur in any examples that I have seen of the closely allied *Pterygoti* from Lesmahagow, many of which have these parts united and well preserved.

A single antennule discovered by Mr. Slimon shows these appendages to have eight articulations; the broad basal joint is serrated along its inner margin, and evidently served the purpose of a manducatory organ. The three succeeding pairs are serrated along their articulations, but are not quite so spinose as in the American species. The *metastoma,* or post-oral plate, is cordiform and quite destitute of any median ridge or ornamentation. Its lateral margin slightly overlaps the anterior margins of the broad basal joints of the swimming-feet, whose serrated palpi fulfil, in this as in all the other species of *Eurypterida,* the chief duty of manducation.

A slight groove or furrow surrounds the anterior and antero-lateral margins of the carapace, gradually thinning off and disappearing at the latero-posterior margins. In his 'Palæontology of New York' (1859, vol. iii, p. 397), Prof. Hall gives the number of articulations in the swimming-feet of *Eurypterus* as "eight, with a terminal palette." He evidently considers the intercalated plate to form a part of the seventh segment, for he says (op. cit., p. 397), "At the line *s* there is a soldered suture, connecting the fixed ramus of the chela with the penultimate joint." In the specimen from Lesmahagow I have been unable to discern more than seven articulations and a terminal palette. The third appears to be the absent joint. Prof. Hall says (p. 397), "In indicating the number of joints, I have been governed by no theoretical views, but simply by the appearances of separation in the parts; and though the two extremities of the *third joint,* as marked, show no articulating processes, the limitation of the parts is distinct, and they may have been separated only by a thin extension of the chitine, and may not be properly articulating surfaces." Supposing, then, this third joint of Prof. Hall's to be absent, we shall agree exactly in the number of articulations in the swimming-feet as well as in their general form. The intercalated plate and minute terminal palette are well seen in *E. lanceolatus,* and were formerly believed to be peculiar to the genus. They have since, however, been met with in *Pterygotus* (page 60), and in *Slimonia* (p. 112). There are at least eight articulations in the antennules, but I cannot positively discern a ninth.

The lateral lobes of the thoracic plate in the individual of this species originally described by us and figured on Pl. XXVIII, fig. 2, and 2 *a* are much deeper, in proportion to the pair of median appendages, and the two intercalated plates are larger than in the American *Eurypteri*.

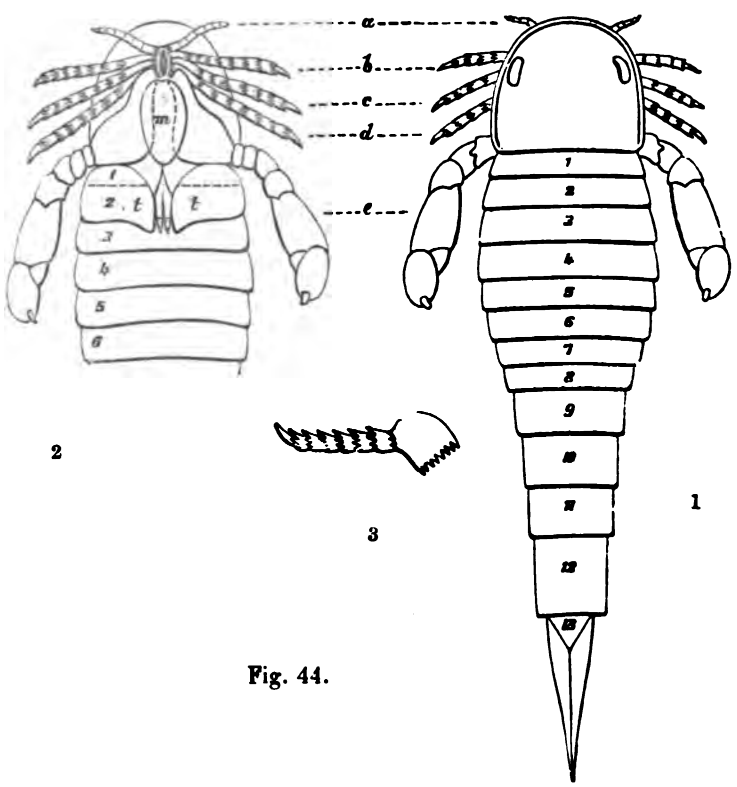

Fig. 44.

FIG. 44.—Diagram-figure of *Eurypterus lanceolatus*, Salter, restored chiefly from fig. 2, Pl. XXVIII. The endognaths are given upon the authority of Mr. Robert Slimon, of Lesmahagow, Lanarkshire.

1. The dorsal aspect of the body. 2. The ventral aspect of the body—*a*, the antennæ; *b*, *c*, *d*, the endognaths; *e*, the ectognaths; *t*, *t*, the thoracic plate, or operculum. 3. One of the antennæ enlarged, from a detached example found by Mr. Slimon.

1—12, body-segments; 13, telson. (See 'Geol. Mag.,' 1864, vol. i, p. 107, pl. v, figs. 7, 8, 9.)

In fig. 1, Pl. XXVIII, however, there is evidence of a much longer median appendage, seen as an impression lying beneath the 9th, 10th, and 11th segments, and probably not less than 8 lines in length. It is highly probable, as stated elsewhere (see ante, pp. 114—118), that this variation in the form of the central appendage is a sexual, and not a specific, character.

The central appendages are each divided into three joints, and the entire surface of the thoracic plate (Pl. XXVIII, fig. 2 *a.*) is closely covered with the usual minute scale-like markings peculiar to this group, which are also observable upon the anterior half of each thoracic segment, the abdominal segments being smooth and free from all ornamentation. The larval eye-spots—so clearly seen in the American species of *Eurypterus*, and in the British *Slimonia* and *Pterygotus*—can scarcely be discerned in *E. lanceolatus*, but they are present, nevertheless, although but feebly indicated.

There is, without doubt, a close affinity between the genera *Eurypterus* and *Slimonia.* The latter approaches the former and recedes from *Pterygotus* proper, not only in the absence of chelate appendages, but also in the more narrow and elongated form of the abdominal segments, and the more lanceolate form of the telson, which in *Pterygotus* proper is broader, less acute, or even bilobed. The chelate antennules in *Pterygotus* are not adapted for *palpi,* but in both *Eurypterus* and *Slimonia* the basal joints of the simple antennæ perform that office.

Eurypterus differs, however, from both *Pterygotus* and *Slimonia* in the position of the eyes, the form of the carapace and the telson, and, lastly, in the structure of the thoracic plate.

Dimensions of E. lanceolatus.—The largest and smallest specimens known are from Mr. Robert Slimon's collection and are now preserved in the British Museum, the former (Pl. XXVIII, fig. 1) measuring $7\frac{1}{8}$ inches in length, and 2 inches across its fourth and widest thoracic segment; the latter (Pl. XXVIII, fig. 3.), measuring only 18 lines in length by 4 lines across its widest segment. A specimen belonging to Mr. Wright, and examined by me in 1864, measures $6\frac{3}{4}$ inches in length, but is much distorted and compressed laterally. The length of the specimen (Pl. XXVIII, fig. 2) in the British Museum is $4\frac{1}{8}$ inches, of which the head forms $\frac{3}{4}$ of an inch, the six thoracic segments 1 inch, the six abdominal segments $1\frac{1}{2}$ inch, and the telson 10 lines. The fourth thoracic segment is the widest, and measures 1 inch across; the succeeding segments taper gradually to the ninth, which is scarcely 7 lines in width; and at the twelfth segment the abdomen is only $\frac{3}{8}$ of an inch wide. The first eight segments are of nearly equal depth, or about $\frac{1}{8}$ of an inch; the ninth, tenth, and eleventh segments are about $\frac{2}{8}$ of an inch in depth, and the twelfth more than $\frac{3}{8}$ of an inch deep. The swimming-feet reach down to the fifth thoracic segment.

The large specimen of *E. lanceolatus* (Pl. XXVIII, fig. 1) measures 7 inches in greatest length and $1\frac{3}{4}$ inch across the widest body-segment. The head-shield is $1\frac{1}{4}$ inch in length and 1 inch 7 lines in greatest breadth. The measurements of the body-rings are as follows:

	Breadth.	Length.
1st segment	1 inch 7 lines and	1 line.
2nd „	1 „ 8 „	2 lines.
3rd „	1 „ 9 „	3 „
4th „	1 „ 10 „	4 „
5th „	1 „ 10 „	4 „
6th „	1 „ 10 „	5 „
7th „	1 „ 8 „	4 „
8th „	1 „ 5 „	5 „
9th „	1 „ 2 „	3 „
10th „	1 „ 0 „	4 „
11th „	10 „	5 „
12th „	7 „	8 „
The telson measures at its widest (proximinal) end	4 „	is 1 inch 7 „

Formation.—Uppermost Ludlow Rock, Upper Silurian.

Locality.—Lesmahagow, Lanarkshire.

All the three specimens here figured are in the British Museum. The rest are in the Museum of Practical Geology.

Species 3.—EURYPTERUS PYGMÆUS:—Salter. Pl. XXVIII, figs. 5, 6, 7.

EURYPTERUS PYGMÆUS, *Salter*, in *Banks*, 1856. Quart. Journ. Geol. Soc., vol. xii, p. 99, pl. ii, fig. 4.

— — *Salter*, 1859. Op. cit., vol. xv, p. 232, pl. x, figs. 4—8.

In Mr. R. W. Banks's paper "On the Tilestones, or Downton Sandstones in the Neighbourhood of Kington, and their Contents," read before the Geological Society of London, December 5th, 1855, we find the first notice of this small Crustacean. The remains appear to have been derived from the quarry at Bradnor Hill, near Kington, between Bradnor Farm and the Quarry House. "The lowest fossiliferous bed exposed in the lane is the equivalent of the Ludlow Bone-bed, a soft liver-coloured layer, varying from two to three inches in thickness, and containing abundance of fossil remains, *Orthocerata*, *Goniophora*, *Orthonota*, *Orbicula*, *Holopella*, *Chonetes*, *Cornulites*," &c. "Above this layer, before the 'Tilestone' is reached, layers of *Orthonota amygdalina* and *Trochus helicites*, much flattened, occur. The uppermost beds are thin shaly beds of Tilestone, containing a *Lingula* of a very small size (probably *Lingula minima*), grouped together in masses, and occasional traces of *Pterygotus*." The uppermost beds, about twelve feet in thickness, are composed of three beds of bluish-white stone, very hard, close-grained, and unfossiliferous.

"Between these upper beds and the underlying bed is a greyish layer, varying from three to six inches in thickness, occasionally of a blackish-grey colour, from the quantity of vegetable remains mixed up with it, and containing on the western side of the quarry the remains of Fish (*Pteraspis*) and of *Pterygotus* and other Crustaceans. This layer, when dry, is tough, and the remains are with difficulty removed from it; but when placed in water it separates easily, wherever the remains occur, and if left in water soon decomposes into mud. It appears to have been just such a muddy sediment, accompanied with sea-weeds, as was suited to Crustaceans. The organic remains in this layer retain their dermal covering, which is often glossy, and in a more perfect state than in the underlying beds of Downton Sandstone. Small, round, rusty nodules, sometimes irregular, occur in this layer in abundance, but no Mollusca.

"The next bed, which is probably identical with the Downton Sandstone, consists of a yellowish-white, close-grained sandstone, on the east side of the quarry passing gradually into a blue and still harder stone, which contains occasional traces of *Pterygotus*, but more frequently *Lingula cornea*. The yellow portion of this bed contains throughout *Pterygotus* and fish remains (*Pteraspis*), with an occasional *Trochus helicites*, but they are not so abundant as in the grey layers and underlying bed. This bed is from three to four feet in thickness.

"This is followed by a grey layer, similar in composition and contents to the grey layer already noticed. The next or bottom bed of the quarry is a yellow sandstone of still better quality, capable of being dressed to a very fine surface, and much used in building. It is about four feet in thickness. The lowest portion of it consists in many parts of the quarry of large flagstones, from a foot to eighteen inches thick, used for gravestones; these lie on the Ludlow Rock, here a very hard unmanageable stone, termed by the quarrymen 'greenstone.' The *Pterygotus* and fish remains occur down to the very bottom, where the spines of *Leptocheles* first appear in considerable abundance; *Trochus helicites*, much depressed, and the small Lingula before noticed, also occur in the lowest portions of the bed."[1]

Mr. Banks adds:—"A specimen of a Crustacean, probably a species of *Eurypterus*, was found in the grey layer before noticed; it is very imperfect; the trace of the dermal covering is slight, and the posterior segments, which would throw a greater light on its proper position, are wanting. The posterior portion of the head, at the junction with the thorax, is bounded by an almost straight line, of an equal width with the bands, which are entire from side to side and without any longitudinal depression. Mr. Salter proposes to name it *E. pygmæus*. One specimen which I lately found had a distinct swimming-foot on the left side, resembling those figured by various authors who have

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[1] R. W. Banks, 'Quart. Journ. Geol. Soc.,' 1856, vol. xii, pp. 94 and 95.

written on the genus."[1] Mr. Banks figures (on plate ii, fig. 4, vol. xii, op. cit.) the small, half-oval carapace, with somewhat remote eyes, as well as a few front body-segments. Mr. Salter ('Quart. Journ. Geol. Soc.,' vol. xv, p. 232, pl. x, figs. 4—8) figures the entire body and caudal joint with the sculpture of the head and body-rings, and he also indicates the form of the small broad swimming-foot (reproduced on our Pl. XXVIII, figs. 5, 6, 7). "The body," writes Mr. Salter, "tapers rapidly backwards; it is not four times the length of the head, and is broadest at about the fourth segment. The first segment is very narrow, not above half the width of the second; and the rest are all transversely broad until the eighth, when they begin to lengthen out, the [twelfth][2] being square. The telson is regularly long-triangular, the length being scarcely more than twice the breadth. It is slightly keeled above; the sides are straight; the apex is not produced.

"The elongation of the last body-joints before the tail helps to distinguish this small species from a closely allied form in the shales of Lesmahagow, Lanarkshire. This has the tail of the same shape, but a shorter head; and the penultimate body-joints are nearly one and a half times as wide as long. In other respects it is very similar. It is described below as *E. chartarius*.[3]

"Of the swimming-foot we have the two expanded terminal joints; taken together, they are as long as the head, and form an oblong oval, the deep notch in the penultimate joint being filled exactly by the oval terminal palette. The lobes on either side of this notch are very unequal, the posterior being much the larger and longer."

Locality.—Downton Sandstone (Uppermost Ludlow Rock) of Kington, Mr. R. Banks's Collection. Upper Ludlow Shales, Ludford Lane, Ludlow, beds of passage at the base of the Old Red Sandstone, in the railway-cutting, Ludlow (Messrs. Lightbody and Marston's Cabinets).

Species 4.—EURYPTERUS ACUMINATUS:—Salter. Pl. XXVIII, figs. 13 and 15.

EURYPTERUS ACUMINATUS, *Salter*. Quart. Journ. Geol. Soc., 1859, vol. xv, p. 233, pl. x, figs. 17 and 19 (?).

"We have," writes Mr. Salter of this species, "the tail-joints only. They are much broader at the base than in *Eurypterus* [now *Stylonurus*] *megalops*;[4] but possibly they belong to the opposite sex, as the individuals are nearly of the same size, and occur in the same strata, namely the passage-shales between the Upper Ludlow Rock and the Old Red Sandstone, in the Ludlow railway-cutting.

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[1] R. W. Banks, 'Quart. Journ. Geol. Soc.,' 1855 p. 99.

[2] The last segment before the telson is always spoken of by Mr. Salter as the eleventh; for at the time when his Memoir was published, 1859, he was unaware of the existence of twelve body segments between the head and the telson. See Introduction, Part I, of this Monograph.

[3] Mr. Salter subsequently concluded that *E. chartarius* was only the young of *E. lanceolatus* (see p. 140).

[4] There appears no reason (save their accidental association together in the same bed) for attributing the series of detached body-rings (referred to here by Mr. Salter, and reproduced on our Pl. XXVIII, fig. 8) to the head-shield of *S. megalops*, which there is good reason to believe, by comparison with the other species, had a more styliform telson than fig. 8 exhibits.

"Telson expanded and cordate at base, the broadest portion being less distant from the insertion than one third the entire breadth. From thence the tail-joint is regularly acuminated, the length being only two and a half times the breadth. The edge is crenato-serrate like the last. We have only the flat under surface."

Locality.—Ludlow, associated with *Stylonurus* (*Eurypterus*) *megalops* and other forms of Eurypterida.

Species 5.—EURYPTERUS LINEARIS:—Salter. Pl. XXVIII, figs. 10, 11, 12.

EURYPTERUS LINEARIS, *Salter*. Quart. Journ. Geol. Soc., 1859, vol. xv, p. 234, pl. x, figs. 15, 16 *a* and *b*.

Of this form Mr. Salter writes—"As this occurs generally in a lower stratum (Upper Ludlow Rock) than *E. acuminatus*, it is little likely to have any relation to that species, though the differences are such as might be due to sex. If, however, *E. megalops* and *E. acuminatus* be one species, *E. linearis* must rank as distinct. The telson, the only part preserved, is greatly more elongated than in the other forms.

"Telson linear, lanceolate, nearly five times as long as wide; the base very little expanded, broadest near the point of insertion, or rather parallel-sided for a short distance, and then attenuated. A strong median carina runs the whole length, elevated into a steep ridge near the origin of the joint, and the edge is so faintly crenate as to appear smooth to the naked eye."

Fig. 10 "shows a broader telson, from the same bed, and it most probably bears the same relation to *E. linearis* that the last-described species does to *E.* [*Stylonurus*] *megalops*. From analogy we must suppose the broader tail-joint to belong to the female, and the narrower one to the male."[1]

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[1] The only "analogy" which I can suppose was present in Mr. Salter's mind, in reference to the expanded form of the telson in *Eurypterus* being indicative of the female and the narrower one of the male, will, I fear, if followed, lead to error.

I can, of course, only infer, but it seems very probable, that Mr. Salter's observation had reference to the abdominal segments in the modern Brachyura, in which the female crab has a broadly expanded abdomen, and the male an exceedingly narrow one.

But as this diversity in form has a direct relation to the office performed by the caudal segments, whether in the female crab, lobster, or prawn, namely, the convoy and protection of the eggs after extrusion from the ovaries and before hatching, we can hardly imagine a part not fulfilling such offices to be so modified. As stated elsewhere (see *antè* pp. 109 and 110, and pp. 114—118) it, is the *antennæ* and the *opercular plate* which in this group of Crustacea undergo important sexual modifications. I consider that the form of the telson is of great value as a *specific* character.

Locality.—The Upper Ludlow Rock of Ludlow, and the Downton Sandstone of Kington, Herefordshire.

Species 6.—EURYPTERUS ABBREVIATUS :—Salter. Pl. XXVIII, fig. 14.

EURYPTERUS ABBREVIATUS, *Salter.* Quart. Journ. Geol. Soc., 1859, vol. xv, p. 234, pl. x, fig. 18.

Mr. Salter characterises this as "A thoroughly distinct species, yet with very similar characters to those of *E. acuminatus*, as if the telson of that species had been greatly abbreviated.

"Telson broadly trigonal at base, forming a nearly equilateral triangle, of which the smooth thickened base forms one angle; the sides expand with a curved outline for about half the length of the joint, then suddenly contract and form a narrow, acuminate, serrated point.

"We have only the under surface; the upper was probably keeled; the lower shows a faint longitudinal elevation proceeding from the thick base to the point. The serræ on the edge are very prominent. Length $\frac{7}{10}$ inch, width $\frac{5}{10}$ inch.

"*Locality.*—Downton Sandstone of Kington, Herefordshire."

Species 7.—EURYPTERUS HIBERNICUS :—Baily, sp. Pl. XXVIII, figs. 16, 17 and 17 *a*.

EURYPTERUS SCOULERI (?), *Salter.* Quart. Journ. Geol. Soc., 1859, vol. xv, p. 232, pl. x, figs. 2 and 3.

PTERYGOTUS HIBERNICUS, *Baily.* Brit. Assoc. Report, Section C, Exeter, 1869, p. 75.

In Mr. Salter's paper "On some new species of *Eurypterus*, &c.," communicated to the Geological Society, June 23rd, 1858, he notices certain fragments of a Crustacean (figured on our Pl. XXVIII, figs. 16, 17 and 17 *a*), from the Upper Old Red Sandstone, Kiltorcan, Co. Kilkenny, Ireland, which he refers doubtfully to *E. Scouleri*, Hibbert. He was led to this conclusion from a comparison of these fossil-remains with a *photograph* of the carapace of *E. Scouleri* in the Andersonian Museum, Glasgow. Mr. Salter calls attention to the curiously reticulato-squamose under-surface (?), with its margin raised into strong suborbicular plicæ and elongated tubercles (See Pl. XXVIII, figs. 17 and 17 *a*), which he compares with those on the margin of the carapace of *E. Scouleri*. From these however, I have satisfied myself they are quite distinct, so far as the fragmentary nature of the remains permit us to judge, although I have no doubt they belong to a species of the genus *Eurypterus*.

In a report to the British Association for the Advancement of Science, Section C, Exeter, 1869, "On the Fossils of Kiltorcan, Co. Kilkenny," by W. Hellier Baily, Esq., F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland, the author recorded the discovery of some portions of a Crustacean which he considered to afford clear evidence of their having belonged to *Pterygotus*.

Mr. Baily then stated his belief as to the probable identity of some of these specimens with others collected at the same locality several years previous, and which have been doubtfully referred by the late Mr. Salter to *Eurypterus Scouleri*. For these Mr. Baily proposed the name *Pterygotus Hibernicus*.

I am informed by Mr. Baily that upon a subsequent visit to this rich locality he obtained other Crustacea to which he applied the names of *Belinurus Kiltorkensis* and *Proracaris Machenrici*.

He has also kindly prepared and forwarded to me careful drawings of several of these fragments, accompanied by notes, from which, by his permission, I have made the subjoined extracts.

The most distinctly marked fragments exhibit the same ornamentation as that seen on figs. 16 and 17, Pl. XXVIII.

Mr. Baily writes as follows:

"In the collections of the Geological Survey of Ireland there are nearly a dozen specimens from this place (Kiltorcan), which appear to me to be referable to *Pterygotus* or *Eurypterus*.

"There are two examples of the carapace or head, which although pressed out of shape, sufficiently indicate the subquadrate form and marginal position of the eyes peculiar to *Pterygotus*.[1] One of these specimens is 3 inches in breadth by about 2 inches in length, the posterior margin being imperfect (it is numbered B. 3400).

"Of thoracic or abdominal segments there are two or three specimens, one being the original fragment before mentioned as doubtfully referred by Salter to *Eurypterus Scouleri*, and figured by him in the 'Quart. Journal Geol. Soc.,' vol xv, pl. x, figs. 2 and 3 *a*, *b*; the characteristic semilunar markings of the surface are well shown in this specimen (F. 1317). See Pl. XXVIII, figs. 16 and 17.

"In another fragment the margin of the lower edge is more irregular in outline and uniformly scalloped (B. 3382). See the subjoined Woodcut, Fig. 45.

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[1] I should be unwilling to form an opinion upon this specimen; judging from the drawing, I should conclude the original is crushed completely out of all recognisable form. It may have been a head-shield, but I cannot say with certainty to what it is referable; if really *subquadrate* in form, it may be *Slimonia*, assuming the eyes to be marginal. The head-shield in *Pterygotus* is now known to be semicircular in outline.

"There is one example of the serrated portion of a 'maxillipede' or 'endognath' which is very well preserved[1] (L. 1688). See Woodcut, Fig. 46.

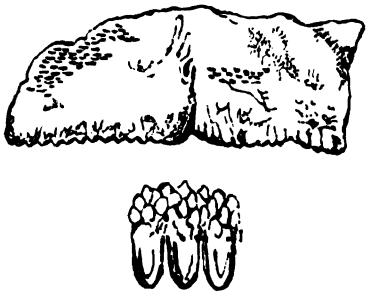


FIG. 45.—Part of one of the body-segments of *Eurypterus Hibernicus*, Baily; and part of the margin enlarged: Devonian, Kiltorcan.

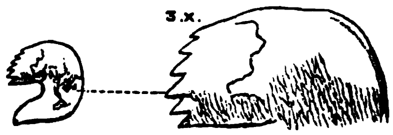
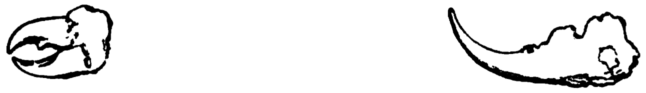


FIG. 46.—Serrated maxilla of one of the endognaths of *Eurypterus Hibernicus*, Baily (natural size and enlarged); Devonian, Kiltorcan.

"Another specimen appears to be the lower portion of a swimming appendage 'ectognath'[2] (D. 1867).

"The chelate termination of an antenna (B. 3374) is not unlike that of one of the modern Crabs, being thick and short, much curved, and provided with one or two blunt tooth-like processes.[3] See Woodcut, Fig. 47.



FIGS. 47 and 48.—Chela, and detached lower ramus of chela of Crustacean, from the Devonian of Kiltorcan.

"Another specimen (B. 3376), which would seem to be the lower ramus of an antennary chela, is larger, more slender, and also much curved.[4] See Woodcut, Fig. 48.

"These specimens being all detached fragments, it is impossible at present to state with any degree of certainty the relation of one with another, or to define the species from such insufficient data. I therefore merely propose the name as a provisional one.

"WM. HELLIER BAILY."

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[1] This endognath or maxillipede is so peculiar in form that I cannot readily suggest a reference for it. It most nearly approaches *Eurypterus punctatus*.

[2] I am unable to recognise the *form* of the ectognath or swimming-foot in this fragment, owing to the distortion of the specimen.

[3] So far as I may venture to speak with certainty of such a detached specimen, I would be unwilling to refer it to the Eurypterida at all. Its form is quite distinct from that of the known chelate antennæ belonging to this group.

[4] If this be the detached lower ramus of a chela, it very probably belongs to some Crustacean not a Eurypterid.

Formation.—Upper Old Red Sandstone.

Locality.—Kiltorcan, Co. Kilkenny, Ireland.

The specimens are preserved in the Museum of the Geological Survey of Ireland, Hume Street, Dublin.

Species 8.—EURYPTERUS BREWSTERI:—H. Woodward. Pl. XXVIII, fig. 4.

EURYPTERUS BREWSTERI, *H. Woodward.* Brit. Assoc. Report, Section C, Bath, 1864, p. 73.

— — *H. Woodward.* Geol. Mag., 1864, vol. i, p. 200, pl. x, fig. 3.

This species of *Eurypterus* was obtained by the Rev. Henry Brewster, of Farnell, near Brechin, from the Old Red Sandstone of Kelly Den, near Arbroath, and its specific name was suggested in honour of its discoverer by Mr. Powrie in 1864, through whom I obtained the loan of the specimen for description.

It consists of a carapace and a portion of the first thoracic segment, slightly displaced; close to which is seen an ovisac, in which are more than twenty ova, more or less compressed.

The carapace measures 2 inches 2 lines in breadth at its posterior border, and 7 lines in length. The sides curve rapidly inwards, leaving the front border only 8 lines broad. The eyes, which are one line in length, are reniform, and within the anterior half of the carapace; they are four lines apart, and have their convex surfaces directed outwards. The margin of the carapace is slightly striated, and there is an inner elevated border in front, 1 line in breadth, which thins out and disappears on the lateral border. The surface of the carapace is slightly wrinkled, but not ornamented in any way.

This species agrees most nearly in general form with *Eurypterus lacustris* of Harlan[1] from the Upper Silurian of New York, but the relative proportions differ considerably.

Interesting as this carapace is, it is rendered still more so by the ovisac associated with it. The so-called *Parka decipiens* of Fleming may include many widely different organisms, but I fully believe that the oviform bodies from the Old Red Sandstone are chiefly the eggs of Crustacea belonging to the order Merostomata.

Formation.—Old Red Sandstone.

Locality.—Kelly Den, near Arbroath, from the Museum of James Powrie, Esq., F.G.S., Reswallie.

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[1] See Hall's 'Palæontology of New York,' p. 407, pl. lxxxi, fig. 3.

Species 9.—EURYPTERUS SCORPIOIDES :—H. Woodward. Pl. XXIX, fig. 1; Pl. XXX, Fig. 9.

EURYPTERUS SCORPIOIDES, *H. Woodward.* Quart. Journ. Geol. Soc., 1868, vol. xxiv, p. 292, pl. ix, fig.; pl. x. fig. 2.

Among the rich collection of fossil Crustacea from Logan Water exhibited by Mr. Robert Slimon at the Meeting of the British Association at Dundee, in September, 1867, were several new forms belonging to the order Merostomata, which have since been acquired for the British Museum.

One of these new forms is represented on Pl. XXIX, fig. 1, by an almost entire individual, measuring 11 inches in length and 5 inches in breadth, having one entire swimming-foot and three pairs of palpi *in sitú,* and presenting a part of the dorsal aspect of the body to view.

The counterpart of the anterior part of the same individual is preserved in the Museum of Practical Geology, Jermyn Street (see Pl. XXX, fig. 9), exhibiting the ventral aspect with the post-oral plate or metastoma ; the bases of the swimming-feet and three pairs of perfect spinose palpi.

Carapace semicircular in front, twice as broad as it is long. Eyes not distinctly preserved, nor ocelli.

Organs of the mouth consisting of five pairs of appendages; the first and most anterior pair not preserved (probably simple palpi, as in *Slimonia, Stylonurus,* and other species of *Eurypterus*). Second, third, and fourth pairs 7-jointed, very robust; fifth, sixth, and seventh joints each armed with a pair of strong recurved spines, the palpi and spines in both specimens directed forwards ; fourth joint armed with several short incurved spines; second and third joints without spines; first joint serving as a *maxilla,* and armed with serrated teeth. Length of palpi 3½ inches, breadth at fourth joint ½ inch. Spines varying from ¾ to 1¼ inch in length, and 2 lines in breadth.

Swimming-feet or *maxillipedes* 7-jointed, 6¼ inches in length. Basal joint somewhat triangular in form, 14 lines long, 10 lines in breadth at posterior border; maxillary border concealed beneath the metastoma; breadth of articulation between the ectognath and second joint 8 lines, length of second joint 8 lines, of third joint 8 lines, of fourth joint 10 lines, of the fifth joint 1½ inch, and breadth 10 lines; sixth joint 1½ inch long by 11 lines broad (a small triangular plate is inserted here as in *Slimonia* and in *Pterygotus*); seventh joint 1¾ inch in length and 9 lines in breadth, with a minute nail 2 lines in length and 1½ line in breadth, inserted at its distal extremity.

Lip-plate or metastoma shield-shaped, having its broadest border directed forward, 10 lines in breadth and the same in greatest length, anterior angles truncated, sides gradually converging towards the posterior border, which terminates in an obtuse angle.

Thoracic plate imperfect, but having a median appendage as in other species. Surface punctate.

Body-segments.—First ½ inch long by 4 inches in breadth, curving upwards at the centre-line downwards on each side and upwards and inwards on its lateral borders.

Second segment 7 lines long in the centre by 4¾ inches in breadth ; margin curved in a corresponding manner to the first segment, ornamented with two subcentral wart-like spots ; surface punctated.

Third segment 10 lines long in the centre by 5¼ inches in breadth ; ornamented in the same manner as the second segment.

Fourth segment 10 lines in length and 5¼ inches in breadth ; border curved, marked subcentrally by two drop-shaped prominences 4½ lines long.

Fifth segment 9 lines in length and 4½ inches in breadth ; ornamented as the fourth segment.

Sixth segment 8 lines in length by 3¾ in breadth ; surface punctated.

Seventh segment 11 lines in length by 2¾ in breadth ; surface punctated.

Eighth segment 1 inch in length and 1¾ inch in breadth ; surface punctated.

Ninth segment 10 lines in length and 1½ inch in breadth.

Tenth segment 10 lines in length and 1½ inch in breadth.

Eleventh segment 11 lines in length and 1¼ inch in breadth.

Twelfth segment 1 inch in length and 1 inch in breadth.

Telson wanting, probably ensiform, as in other species of *Eurypterus.*

The punctate ornamentation is well seen on the anterior body-segments, and is at once readily to be distinguished from the scale-like markings observable on the body of *Pterygotus* and *Slimonia.*

Formation and Locality.—Uppermost Silurian, Lesmahagow, Lanarkshire.

Species 10.—EURYPTERUS PUNCTATUS :—*Salter*, sp. Pl. XXIX, fig. 2.

PTERYGOTUS PUNCTATUS, *Salter.* Mem. Geol. Surv., Mon. I, 1859, p. 99, pl. x ; pl. xi, figs. 5—9, and 12—15 ; pl. xiii, figs. 5, 6, 9, 10, 11, 14.

EURYPTERUS PUNCTATUS, *H. Woodward.* Quart. Journ. Geol. Soc., 1868, vol. xxiv, p. 290.

This species, established by Mr. Salter in 1859, upon a series of detached appendages and fragmentary remains from the Upper and Lower Ludlow Rocks of Leintwardine, Shropshire, is closely related to, but distinct from, *Eurypterus scorpioides*, just described, from Logan Water.

I include under this species the fragments of body-joints drawn on pl. x, 'Mem. Geol. Surv.,' Mon. I, the more or less fragmentary remains of six endognathary palpi and three swimming-feet or ectognaths drawn on pl. xi (op. cit.) [the most perfect of these last-named organs is reproduced on Pl. XXIX, fig. 2]; also the remains on pl. xiii (op. cit) attributed to *Pterygotus* (now *Eurypterus*) *punctatus* by Mr. Salter.

I would, however, venture to exclude :—Firstly, the remains of the *chelate antennæ*[1] —my reasons for so doing being that all the species of Merostomata with spinose palpi have *small*, *simple antennules* (*e.g. Eurypterus*, *Stylonurus*, *Slimonia*).

Secondly, the *lip-plate*.[2] The form of the lip-plate is very characteristic of the separate divisions of this genus; and I am not aware of any other species which possesses such a metastoma as is found in *E. scorpioides*, and which, from the detached plate now figured (see Woodcut, Fig. 50, p. 155), I doubt not, also marked *E. punctatus*, the Leintwardine species. I would therefore suggest that the detached lip-plate ('Mem. Geol. Surv.,' Mon. I, pl. xi, fig. 4) must have belonged to some species of another genus—the form of the plate being nearer that of *Slimonia acuminata*.

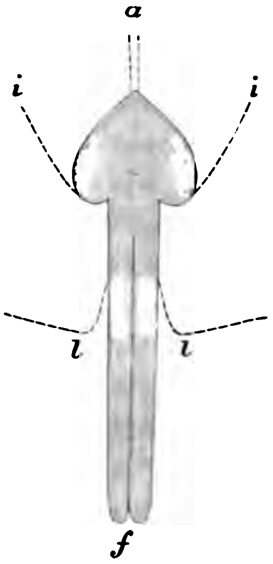

FIG. 49.—Median appendage of the thoracic plate, or operculum, of *Eurypterus punctatus*. *a* would be the centre of the attached border; *i*, *i*, the position of the intercalated triangular plates uniting the median appendage with *l*, *l*, the two lateral alæ of the operculum; *f*, the free extremity of the median appendage.

Thirdly, the *telson*. Mr. Salter observes that "it is yet wanting," and that "in all probability it was not unlike that figured on pl. x, fig. 11, which has possibly something to do with it." On the fragment referred to I will not venture to give an opinion, but will only observe that, as far as I can ascertain by a careful comparison, such a form as *E. punctatus* would have had an ensiform telson, as in the other *Eurypteri*, with which I venture to place it.

The characters by which the fragmentary remains associated together under this name have been distinguished are—the form of the joints of the palpi, with their pairs of long, slender, recurved spines, and their well-marked basal joints (*coxognathites*); the form of the great swimming-feet (see Pl. XXIX, fig. 2), expanded in the penultimate joint, and attenuated at their extremities; the peculiar shield-shaped *metastoma* or post-oral plate (Woodcut, Fig. 50); and, lastly, the distinct punctate ornamentation which characterises the surface of the body-segments and appendages.

Mr. Salter writes (op. cit., p. 99), "Of the *carapace* or *eyes* we have yet no trace. But the *epistoma* presents us with a singularly neat character for the species." This specimen, of which we give a woodcut above (see Fig. 49), is undoubtedly the median appendage of the thoracic plate.[1] The upper portion is broadly sagittate or spear-shaped; the lower portion is quite straight and linear and is divided down the centre into two equal parts for 1¾ inch, or nearly its entire length; reminding one of the corresponding appendage in the thoracic plate of *E. lanceolatus*, which is also bifid (see Pl. XXVIII, fig. 2 *a*). The surface is destitute of ornamentation.

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[1] Pl. xi, figs. 1, 2, 3, 'Mem. Geol. Surv.,' Mon. I.

[2] Pl. xi, fig. 4, op. cit.

Although I cannot accept the detached *lip-plate* (see pl. xi, fig. 4, 'Mem. Geol. Surv.,' Mon. I), referred by Mr. Salter to this species, as really belonging to it, I am fortunately in possession of a very fine example, also from Leintwardine, which was left with me by Mr. Salter for examination some years ago, and from the fact of its close agreement in form with the lip-plate of *E. scorpioides* just described (see Pl. XXX, fig. 9), I feel little hesitation in ascribing it to *E. punctatus*.

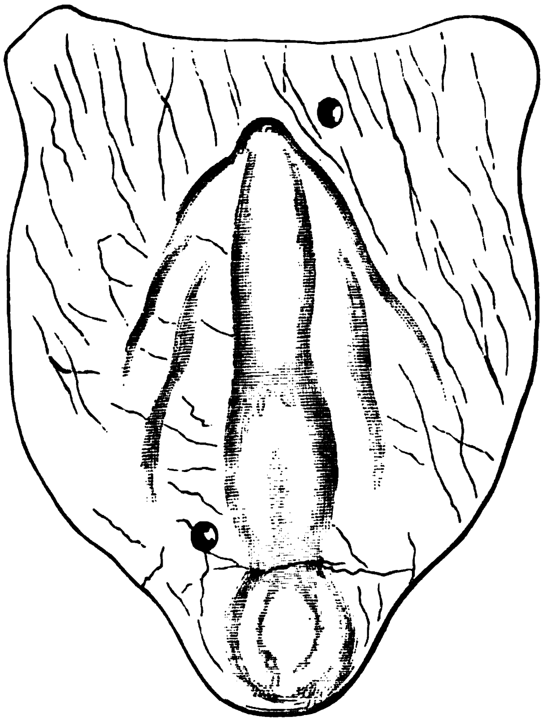

FIG. 50.—Lip-plate of *Eurypterus punctatus*, Salter, sp., from the Lower Ludlow, Leintwardine, Shropshire. Reduced one-third.

Form and dimensions of detached lip-plate (see Woodcut, Fig. 50), referred to *E. punctatus*:—Form, that of an armorial shield with its anterior corners truncated; greatest anterior breadth 4 inches, length 5 inches; sides curving inwards, and again expanding, then terminating posteriorly in a rounded margin only 1½ inch in breadth.

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[1] This part is described by Mr. Salter as the "epistoma" or the "conjoined epistoma and labrum" in this and in all other species in his Monograph.

The other appendages of the head of *E. punctatus* are—1. The *endognaths* and *palpi* (see Mem. Geol. Surv., Mon. I, pl. xi, figs. 5—8; and pl. xiii, figs. 9, 10, 11). Mr. Salter writes:—"There are several specimens, and they present some strong characters for the species. Pl. xiii, fig. 9, and pl. xi, figs. 7 and 8, show portions of the palpi, and fig. 5 an endognath with its entire palp attached, and in the proper position in respect of the great swimming-foot *c*." From this specimen it would appear that the remarkable spines of the palpus were directed forward. "Figs. 8, 9, show the great size these appendages obtained. The teeth of the maxillary piece (fig. 6 *a*, *a**) are small, short, and obliquely conical, not curved, and as in some other species striate; there are about seven distinct and six smaller ones, which last are either connected by a horny plate (as in *P. anglicus*, pl. vii, fig. 5 *b*), or are confused with setæ; the state of preservation does not permit us to decide which. The margin near the teeth is punctate, indicating the presence of hairs or setæ. In some specimens the teeth are narrower and sharper. The great palpi (of which fig. 6 only shows the base at *b*, and fig. 5 a nearly perfect one *in sitú*) are broader at their base than the length of the serrate border *a*. They consist of only five joints, all except the basal one bearing (a pair ? of) curved processes, while the terminal one, *g* in fig. 8, might even be considered as an additional joint.[1] The specimen (pl. xiii, fig. 9) obtained since plate xi was completed shows all the joints complete, and these resemble plate xi, fig. 7, in their elongate form.

"Fig. 5 has much shorter joints, and may very possibly belong to a different pair of maxillæ. In this figure the first joint is very broad and large, subquadrate, tapering but little, rather longer than broad, and bears apparently no curved process. Its edge is spinose (fig. 6 *b*). The third, fourth, and fifth are, in figs. 5 and 8, not very different in size, and nearly square, while in fig. 7 the proportions are longer. All have the great curved spines placed about the middle of the joint.

"In the perfect palpus (pl. xiii, fig. 9) the proportions of the joints are as follows:—The basal one is smaller than the second, about two thirds its length, and of a roughly triangular or trapezoidal shape, the base smallest. The second is longest, half as long again as its breadth; the third and fourth much shorter, the fifth only half as long as broad, and bearing one curved spine at its outer angle, and the other (*g*) at its tip.

"The second, third, and fourth joints are subcylindrical, convex at their outer margin, and bear the curved spines about the middle of the joint. The terminal articulation (*g*), if it be a separate joint, consists only of the curved process, but is probably only the opposite spine of the fifth joint, seen obliquely; and in this view there would be five joints only to the palpus, each joint bearing a pair of processes, as is certainly the case in pl. xiii, fig. 11.

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[1] Although the specimens from Church Hill look as if there were only a single process to each joint, yet, as in the palpus of this species figured in plate xiii, fig. 11, there is a pair of these organs; it is most likely all the other specimens had two. In this view the two processes, *f*, *g*, would belong to the terminal fifth joint.

"The processes themselves are directed obliquely outwards and forwards; they are long, curved, sabre shaped, and much compressed, fully three times as long as the width of the joints, to which they are attached by a swelled base. They are striated longitudinally, the striæ, eleven or twelve in number, sharply impressed, not continuous except near the tip, but interrupted alternately (pl. xiii, fig. 10) for wide spaces, so that the number of striæ appears little more than half what it really is. Nor are the striæ quite parallel to the sides, for they abut obliquely against the concave side towards the tip of the process. Here and there some striæ are stronger than the rest.

"Near the base of the processes the striæ are still more interrupted and run into short impressed lines or punctæ."

The subjoined woodcut (Fig. 51) of the endognath of *E. punctatus* (the outline of which is partially restored from *actual* specimens figured by Mr. Salter and from others in the British Museum) will, perhaps, best explain the peculiar form of these organs, and also exhibit their close correspondence with the same appendages in *E. scorpioides* (see Pl. XXIX, fig. 1, and XXX, fig. 9, accompanying this part).

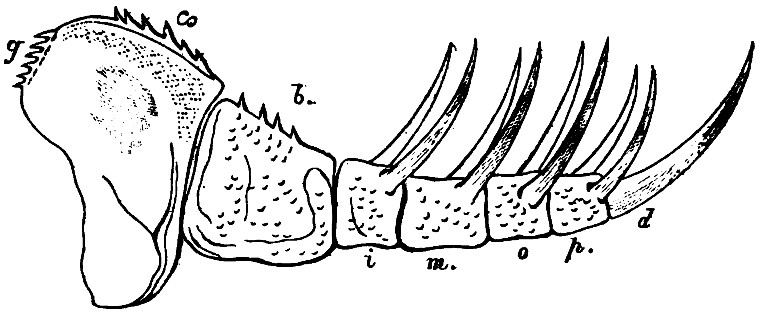

Fig. 51.—Endognathary palpus of *E. punctatus*, Salter, sp., restored from actual specimens, from the Lower Ludlow, Church Hill, Leintwardine, Shropshire, drawn of the natural size. Some of the fragments figured by Mr. Salter would indicate appendages twice as large as this figure.

"The specimens on pl. xiii, figs. 5, 6, 11" (op. cit.), writes Mr. Salter, "are from the Upper Ludlow Rock. Fig. 11 is a very perfect joint of the palpus, with both spines attached; and figs. 5 and 6 show the characteristic long plicæ. Fig. 6 at least would answer best to one of the long joints of the antennæ; it is but a cylindrical fragment of the proximal end, and has the contraction which is visible in the corresponding joint of *P. anglicus* (see pl. iv, fig. 4 *c*, op. cit.) At this part the plicæ are very numerous and small; in the body of the joint they are large, prominent, and elongate, and with the channel-like depression and its bounding ridges (fig. 6 *a*) magnified. They are somewhat unequal in size, and set at more than their diameter apart from one another."

"The *swimming-feet*," writes Mr. Salter (plate xi, figs. 12—15) "are very different in proportion to those of *P. anglicus*, the terminal joints occupying a considerably greater length, and being abruptly wider than the rest. Of the great basal joint (*c o*, in fig. 5) but little is preserved, but a larger specimen (fig. 12) shows it to have been roughly squamose, especially along its basal edge, the narrow squamæ projecting as small spines; the rest of the surface is closely imbricated with smaller plicæ. Pl. xiii, fig. 14, is very possibly the serrate inner lobe of this joint. The second joint (*b*) is large in proportion to the rest, and widens from the base to its truncated apex. The third (*i*) is subtriangular, the blunt apex of the triangle being anterior, and the edge articulating with the next joint nearly straight or but slightly curved. The fourth joint, on the contrary, is an obtuse triangle, of which the broad base is forward and moderately arched, but not projecting as in the *P. anglicus*. It contracts rapidly behind, where it has a narrow deep notch to receive the articulating process of the next joint. This (*c a*) is the fifth, a remarkably short wide articulation, almost buried in the concave edge of the great penultimate joint, and curved to follow the convex border of the triangular fourth joint. It is marked by a strong transverse ridge. All these joints may be seen in fig. 5, but in a far less perfect state than in the fine specimen, fig. 13. The penultimate joint (*p*) is very large, nearly three inches long, and about half as broad. It is oblong, with two rounded unequal lobes, and deeply notched at each end (the distal notch at the end being the deepest), so that the joint overlaps the proximate joints at either end. The hinder margin of the joint is more convex at first, then somewhat excavated, while the anterior margin is straight, or nearly so; the hinder lobes at both ends are larger than the anterior ones, the proximal one, which overlaps the small fifth and fourth joints, being broader and rounder, and the distal one, which abuts against the terminal palette, being long and narrow.

"The terminal joint (*d*) is very long, nearly three inches by nine tenths of an inch wide, elongato-lanceolate, but rounded at the tip, its anterior margin a little convex and plain-edged half way down, the posterior slightly concave and rather strongly serrate; the serræ are shallower on the anterior margin, and deepest round the tip."

The largest and most perfect of these organs are reproduced on Pl. XXIX, fig. 2, which corresponds with Mr. Salter's pl. xi, fig. 15, 'Mem. Geol. Surv.,' Mon. I, 1859.

Body-segments.—Concerning these Mr. Salter writes—"Of the first *body-ring* a fragment an inch and a half long and one inch wide is figured (pl. x, fig. 2).

"It is the semicircular sweep of the outer edge of the segment, where it fits into the scooped-out portion of the succeeding (second) one. The rounded margin *a* is serrated, the serrations pointing backward. The sculpture is very minute, prominent, and confined to the forward half, except a few marginal plicæ on the hinder edge. All are longer than wide. Fig. 2 *a* shows them magnified. Fig. 3 is, without much doubt, the second thoracic segment. It is wider at the sides than in the middle, and turns up abruptly at the forward angle to form the characteristic process. Fig. 4 appears to be a larger specimen of the third ring, it has the same characters of ornamentation. In both the central portion is less arched than in *P. anglicus* or *P. arcuatus*, and the sides less obliquely and minutely crenulate.

"A narrow (articular ?) furrow runs along the middle portion of the anterior edge, followed by a convex ridge, which is bounded by a row of prominent minute tubercles, extending a good way out, and nearly to the lateral margins. Behind this the anterior third of the segment is occupied by the sculpture, which is much more prominent and tubercular, and less scale-like than in the large Scotch species."

Mr. Salter adds—"There is evidence of at least three, if not more, of the thoracic rings. The hinder segments were decidedly longer in proportion to their width than in *P. anglicus* or *P. gigas.* We have also the swimming paddles, which, without the great coxal joints, were seven inches long, expanded in the penultimate joint, and attenuated at their tips; and the mandibles, the palpi of which were strongly fringed with long curved processes. As all these present distinctive peculiarities from other species, and as the tuberculation on the various specimens found in this bed agrees in character, it is fair to combine them as a single species, and figure them all upon one plate."

As regards the form of the body-segments, Mr. Salter's evidence is most valuable in confirmation of the identity of these remains; for in the Survey Monograph he figures (p. 101) five of the anterior body-rings from Leintwardine, which agree closely in form with the specimen from Lanarkshire. He also observes (p. 99) that "the hinder segments were decidedly longer in proportion to their width than in *Pterygotus Anglicus*, or *Pt. gigas.*" Indeed, one of the segments which he has figured (Mon., pl. x, fig. 5) most clearly shows this to be the case.

From the evidence derived from the nearly related Lanarkshire specimens (already described), I venture to refer this form to *Eurypterus;* it will probably come near Hall's *Eurypterus pachycheirus.*[1]

But the specimens from the Lower Ludlow Rock give evidence of a species *twice the size* of that occurring in Lanarkshire; there are also sufficient points of distinction in the form of the metastoma, the joints of the swimming-feet, the armature of the palpi, &c., to distinguish them specifically. I therefore propose to retain the name of *punctatus* for the Ludlow remains, as indicated, adding thereto the great lip-plate (see Woodcut, Fig. 50) already referred to.

I will merely add that I have received from Mr. Charles Ketley a series of five narrow abdominal segments of a crustacean from the Wenlock Limestone, Dudley, the markings upon which lead me to refer it to *Eurypterus punctatus.* Other portions, bearing similar *punctate* ornamentation, easily distinguished from the ordinary squamate markings so characteristic of *Pterygotus*, have been obtained, and obligingly submitted to me for examination, from both the Wenlock Shale and Limestone, by Mr. John Gray, Mr. E. Hollier, Mr. Allport, and Mr. Johnson.

Formations and Locality:—Upper Ludlow Rock, Whitcliffe, Ludlow, Kendal, Westmoreland; Lower Ludlow Rock, Church Hill, Leintwardine; Wenlock Limestone and Shale, Dudley.

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[1] And probably also near his subgenus *Dolichopterus.*

Species 11.—EURYPTERUS OBESUS:—H. Woodward. Pl. XXX, fig. 8.

EURYPTERUS OBESUS, *H. Woodward.* Quart. Journ. Geol. Soc., 1868, vol. xxiv, p. 293, pl. x, fig. 1.

This little form is remarkable for the great obesity of the thoracic somites, the breadth of the fourth segment being equal to the length of the first eight segments.

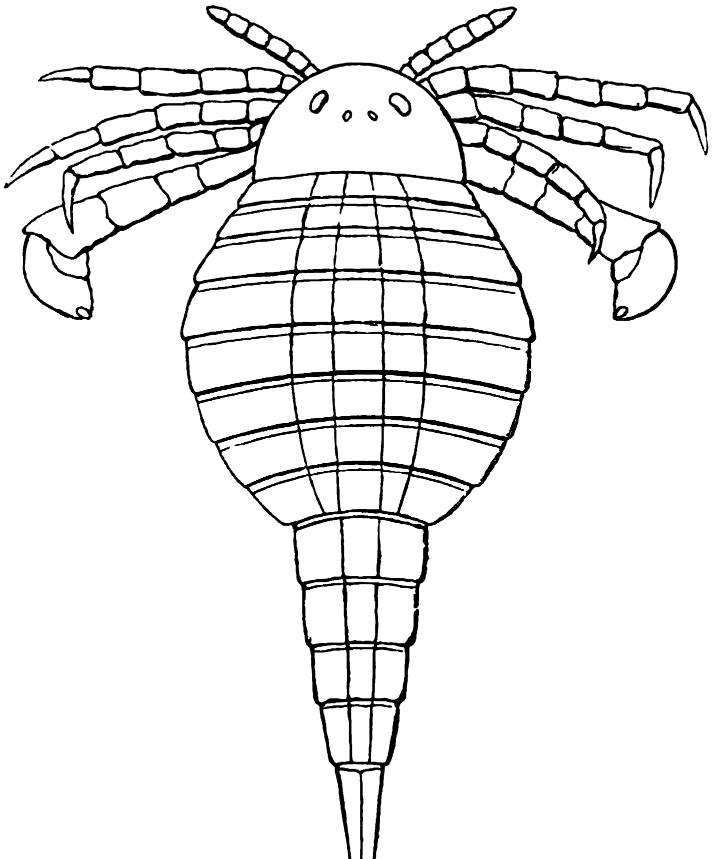

FIG. 52.—Diagram-figure of *Eurypterus obesus*, H. Woodw. Restored and enlarged from the specimen figured on Plate XXX, fig. 8.

The carapace is 6 lines in breadth at its posterior border; the lateral and anterior borders form a semicircle; the length is 3 lines.

The integument of the carapace and segments was extremely thin, as shown by the puckered condition of the entire surface. The dorsal surface, which is exposed to view, displays two eyes, placed 2½ lines apart, and two subcentral ocelli.

Five pairs of appendages are preserved *in sitû*:—

First, a pair of simple cylindrical antennæ (7 ?-jointed), 4 lines in length.

Second, third, and fourth pairs alike, and about 9 lines in length; seventh joint unguiform.

Swimming-feet, 1 inch in length; third, fourth, and fifth joints small and somewhat narrow; sixth as broad as it is long; seventh, nearly oval, with small terminal talon, and united to the sixth joint by a small intercalated triangular plate.

Body-segments.—No ornamentation is visible on these, save a quadrilinear series of markings extending to the seventh segment, but bilinear markings are seen on the eighth and ninth segments. First segment 6 lines in breadth and 1 line in length; second segment 8 lines in breadth and 1 line in length; third segment 9½ lines in breadth and 1 line in length; fourth segment 11 lines in breadth by 1¼ line in length; fifth segment 11 lines in breadth by 2 lines in length; sixth segment 11 lines in breadth by 1¾ line in length; seventh segment 10 lines in breadth by 1½ line in length; eighth segment 7 lines in breadth by 2 lines in length; the border of this segment slopes rapidly inwards posteriorly, and is arched laterally; ninth segment 3 lines in breadth and 2 lines in length; tenth segment 3 lines in breadth and 2 lines in length; eleventh segment 2¼ lines in breadth and 2¼ lines in length; twelfth segment 2 lines in breadth and 2½ lines in length; telson broken, no doubt ensiform when properly preserved.

The annexed woodcut (Fig. 52) restoration may serve to convey some idea of this singular form of Eurypterid, which may possibly be a larval stage of *E. scorpioides* already described (see Pl. XXIX).

Formation.—Uppermost Ludlow Rock (Upper Silurian).

Locality.—Lesmahagow, Lanarkshire.

The specimens are preserved in the British Museum.

Species 12.—EURYPTERUS BRODIEI:—*H. Woodward.*

Eurypterus Brodiei, *H. Woodward.* Quart. Journ. Geol. Soc., 1871, vol. xxvii, p. 261.
— — *H. Woodward.* Trans. Woolhope Club, 1871.
— — *H. Woodward,* Brit. Assoc. Report, Section C, Liverpool, 1870, p. 91.

In March, 1869, the Rev. P. B. Brodie, F.G.S., communicated to the Geological Society a short account of the occurrence of remains of *Eurypterus* and *Pterygotus* at Purton (see 'Quart. Journ. Geol. Soc.,' xxv, p. 235). Mr. Brodie stated that the specimens collected at that time and submitted to me were not considered to be new; in fact, they consisted, for the most part, of fragments of *Pterygotus*[1] (*P. Banksii*) and *Eurypterus*[2] (*E. pygmæus*, *E. acuminatus*, *E. abbreviatus*, &c.), already noticed in this Monograph and previously described by Mr. Salter elsewhere.

Since that communication was read, Mr. Brodie has again explored this locality, and has forwarded to me several parts and an almost entire example of a *Eurypterus*, which differs considerably from any species previously examined by me, and of which I subjoin a short notice.

53.

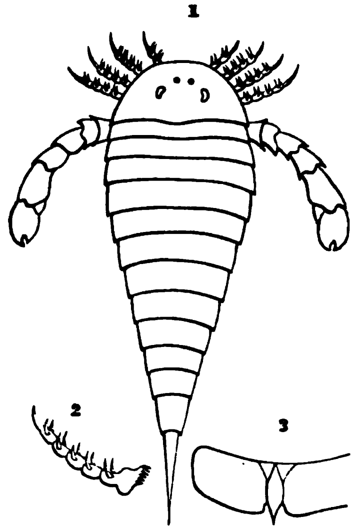

FIG. 53.—*Eurypterus Brodiei*, H. Woodw.
1.—Outline restored, natural size. Passage-beds from the Uppermost Silurian to the Old Red Sandstone, Perton, near Stoke Edith, Herefordshire.
2.—Palpus (enlarged).
3.—Thoracic plate (enlarged).

The most perfect specimen, from which the restored outline (Fig. 53) is taken, measures $2\frac{3}{4}$ inches in length and 10 lines in its widest thoracic segment. All the somites are united; and one of the swimming-feet, although injured, is still in place. The head, which is semicircular in outline, measures 4 lines in length by 9 lines in breadth; the eyes are sub-central, and the ocelli nearly central, as in the other species of *Eurypterus*. The first six segments (thoracic) succeeding the head measure together 9 lines in length; commencing with a breadth of 9 lines, they increase at the third segment to 10 lines, and diminish at the sixth segment to 7 lines in breadth. The segments increase in length and diminish in breadth very evenly from the third segment backwards. The borders of all the anterior segments are curved, and the posterior angles slightly produced and acutely pointed.

The six posterior (abdominal) segments diminish in breadth backwards from 6 lines to 2 lines, and increase, in the same direction, in length, from $1\frac{1}{2}$ line to $2\frac{1}{2}$ or nearly 3 lines, the body being terminated by a slender ensiform telson, or tail-spine, 7 lines in length. No sculpture is apparent on the segments or head; but the integument composing the former indicates its tenuity by abundance of plicæ and wrinkles. The thoracic plate (Fig. 53, 3) is very characteristic, differing in the form of its median appendage from that of any previously described species. It is 9 lines broad and $2\frac{1}{2}$ in depth; the median appendage is spindle-shaped in outline, and is $3\frac{1}{2}$ lines in length and $1\frac{1}{2}$ line broad. The swimming-foot is $2\frac{1}{2}$ lines in width and $\frac{3}{4}$ of an inch in length, exclusive of the basal joint. The species agrees closely, in the form of its swimming-feet, with the American and Russian *Eurypteri*, having

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[1] See 'Mem. Geol. Surv.,' Mon. I, 1859, pl. xii, figs. 22—46, p. 51.

[2] 'Quart. Journ. Geol. Soc.,' 1859, vol. xv, pl. x, p. 229.

the same intercalated plate between the ultimate and penultimate joints, and also the minute terminal palette at the end of the seventh segment.

Numerous detached endognathary palpi occur associated with this form, furnished with short recurved spines (Fig. 53, 2) arranged in pairs upon each segment, doubtless referable to the same species. I have proposed to name this form *Eurypterus Brodiei*, after its discoverer.[1]

Formation.—Passage-beds from the Uppermost Silurian to the Old Red Sandstone.

Locality.—Purton, near Stoke Edith, Herefordshire.

BAD AND DOUBTFUL SPECIES.

⁂ The following species have been somewhat *doubtfully* referred by Mr. J. W. Salter to *Eurypterus*, but I think sufficient evidence is given below to prove that a portion, at least, of the remains referred by him to *Eurypterus? mammatus* are really plant-remains, and that the remainder must, for the present, be classed with M. Jordan's *Arthropleura armata*, from the Coal-measures of Saarbruck, Rhenish Prussia, a very anomalous Crustacean, but certainly not a *Eurypterus*.

Eurypterus ferox, I think, may with propriety be referred to the Myriapoda under Messrs. Meek and Worthen's genus *Euphoberia* (see below, p. 171).

"*EURYPTERUS? MAMMATUS:*"—*Salter*. Pl. XXIV, figs. 2—6.

Eurypterus (Arthropleura?) mammatus, *Salter*. Quart. Journ. Geol. Soc., 1863, vol. xix, p. 85, figs. 1—7.

This species was determined by Mr. J. W. Salter in 1863, from fragments referred by him to the head (Pl. XXIV, figs. 2 and 3), to the lateral portions of the body-segments, and parts nearer to the tail; but of the central surface of the carapace, of the eyes, or of the appendages, nothing is known.

The first fragment was discovered by Mr. Gibbs, the intelligent Collector of the Geological Survey, in splitting up the shales at the mine-top, Pendleton Colliery, Manchester. Other specimens[2] were afterwards obtained by Messrs. Gibbs and Rhind, who ascertained the exact bed from which these remains were derived, and which proved to be the "Ferny Metal," under the "Big Coal" or "Ram's Mine."

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[1] See 'British Association Reports,' Liverpool, 1870, p. 91.

[2] The specimens drawn on Pl. XXIV, figs. 2, 3, 4, 5, and 6, and preserved in the Museum of Practical Geology, Jermyn Street, are all which have been met with of this species. From the account given by Mr. Salter, one would have expected a larger series of fragments.

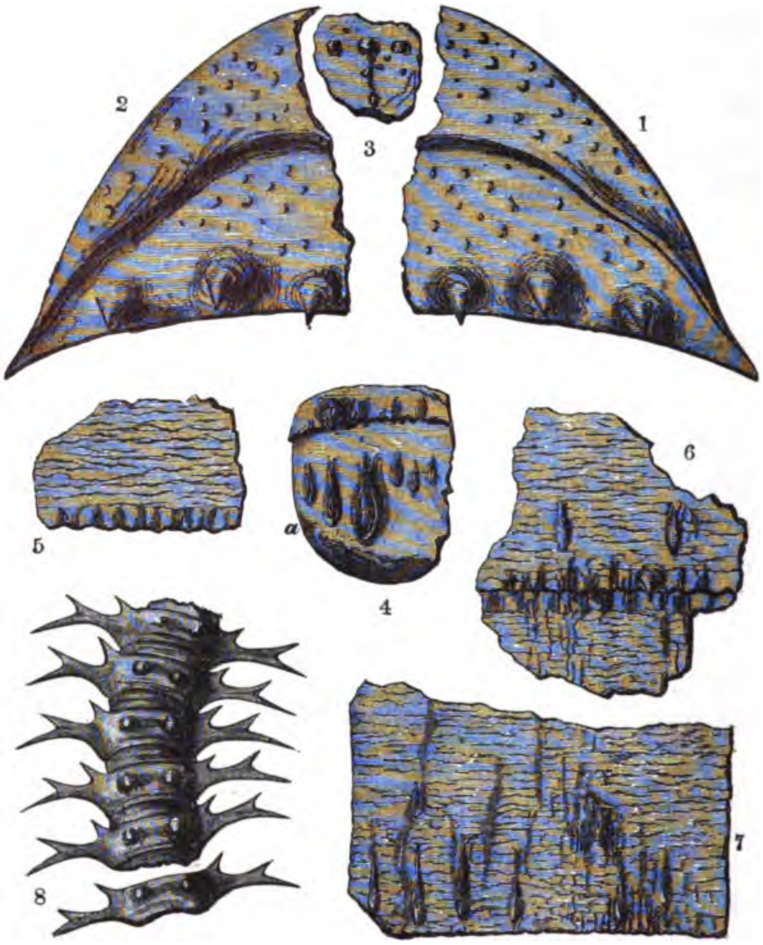

FIG. 54.—(1–7).—***Eurypterus* (*Arthropleura ?*) *mammatus***, Salter.
(8).—***Arthropleura* (*Euphoberia ?*) *ferox***, Salter.
(Woodcut from the 'Quart. Journ. Geol. Soc.,' 1863, vol. xix, p. 84.)

The plants occurring in this bed, noticed by Mr. Salter, are—

Lepidodendron obovatum, Sternb.
,, *Sternbergii*, Brong.
,, *elegans*, ,,
Neuropteris Loshii, Lindl.
,, *heterophylla*, Sternb.

Neuropteris gigantea, Sternb.
Cyclopteris flabellata, Brong.
Sphenopteris obtusiloba, ,,
,, *latifolia*, ,,
and some others.

The bed lies rather high in the "Middle Coal series."

The specimen figured on Pl. XXIV, fig. 2, is considered by Mr. Salter to be the lateral portions of the head-shield, which he thinks must have been at least 8 or 9 inches across. It shows a strongly arched border running out into a short acuminate broad spine, into which a strongly curved sharpish ridge runs from about the upper central portion. The space outside and above the ridge is flat, and is ornamented with small rounded tubercles scattered irregularly over its surface; below the ridge there are fewer tubercles, but near the hinder border there are two large mammillated tubercular spines (and part of a third) ranged about equidistant from one another; they are directed backwards, and are fully a third of an inch in length, and as much in diameter at the swollen base.

Another fragment (Pl. XXIV, fig. 3), also referred by Mr. Salter to the head, shows large and small tubercles upon its surface.

Mr. Salter speaks of "at least six, and probably more, of the large mammillated tubercular spines along the hinder border" (of fig. 2, Pl. XXIV). The explanation of this is to be found by referring to the woodcut illustrating Mr. Salter's paper, which by the kindness of the Council of the Geological Society we are able to give above, p. 164, Fig. 54 (see 'Quart. Journ. Geol. Soc.,' vol. xix, p. 84), when it will be seen that this specimen (fig. 2) has been drawn *twice over* (once reversed, and once in its natural position) so as to give the effect of a crescent-shaped shield. But only the piece represented on our Plate as fig. 2[1] exists, and after careful comparison I am quite unable to refer it to the head-shield of any known Crustacean.

Referring to the above woodcut Mr. Salter observes, "Although I have supposed figs. 1 and 2 to belong to the head, I have really little else to recommend this view than the great comparative size and breadth, and the general form, which is like that of the hinder angles of the head of the Scotch *Eurypterus*."[2]

Mr. Salter then proceeds to contrast his *Eurypterus mammatus* with the *Arthropleura armata* of Jordan, a species founded upon the fragments of a large Crustacean from the Coal-measures of Saarbruck, Rhenish Prussia.

If the subjoined woodcut (Fig. 55, B) of *Arthropleura armata* be compared with Pl. XXIV, fig. 2, a somewhat similar piece (marked *p*), having a corresponding raised border and similar arrangement of tubercles, will be seen, suggesting that this pointed portion (fig. 2) may more likely be the pleuron of a trilobed segment. This interpretation, although rejected by Mr. Salter, seems to me, on many accounts, more probable than the alternative one which he has adopted, namely, that of supposing it to be the posterior angle of the head-shield of *Eurypterus*, with which indeed it seems exceedingly difficult to associate it.

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[1] It is quite apparent, however, from Mr. Salter's description, that he was under the impression that *two* specimens existed *in reality* as well as in his figure. I have therefore specially noticed this, lest hereafter it should be supposed that one of these curious fragments had been lost.

[2] If by the Scotch *Eurypterus* Mr. Salter refers to *E. Scouleri*, a comparison between the fragment of *E. mammatus* (Pl. XXIV, fig. 2) and the entire head of *E. Scouleri* (Pl. XXVII) will satisfy us that such a hinder angle could not possibly be fitted to the carapace of the latter; the *curvature* and ornamentation being both incongruous. No other form with which we are acquainted could have required so large an epimeral piece save the great Devonian *Stylonurus Scoticus*.

Assuming it to be, like Jordan's *Arthropleura armata,* part of the body-segment of some large palæozoic Crustacean (such as *Stylonurus Scoticus,*[1] or that singular form named

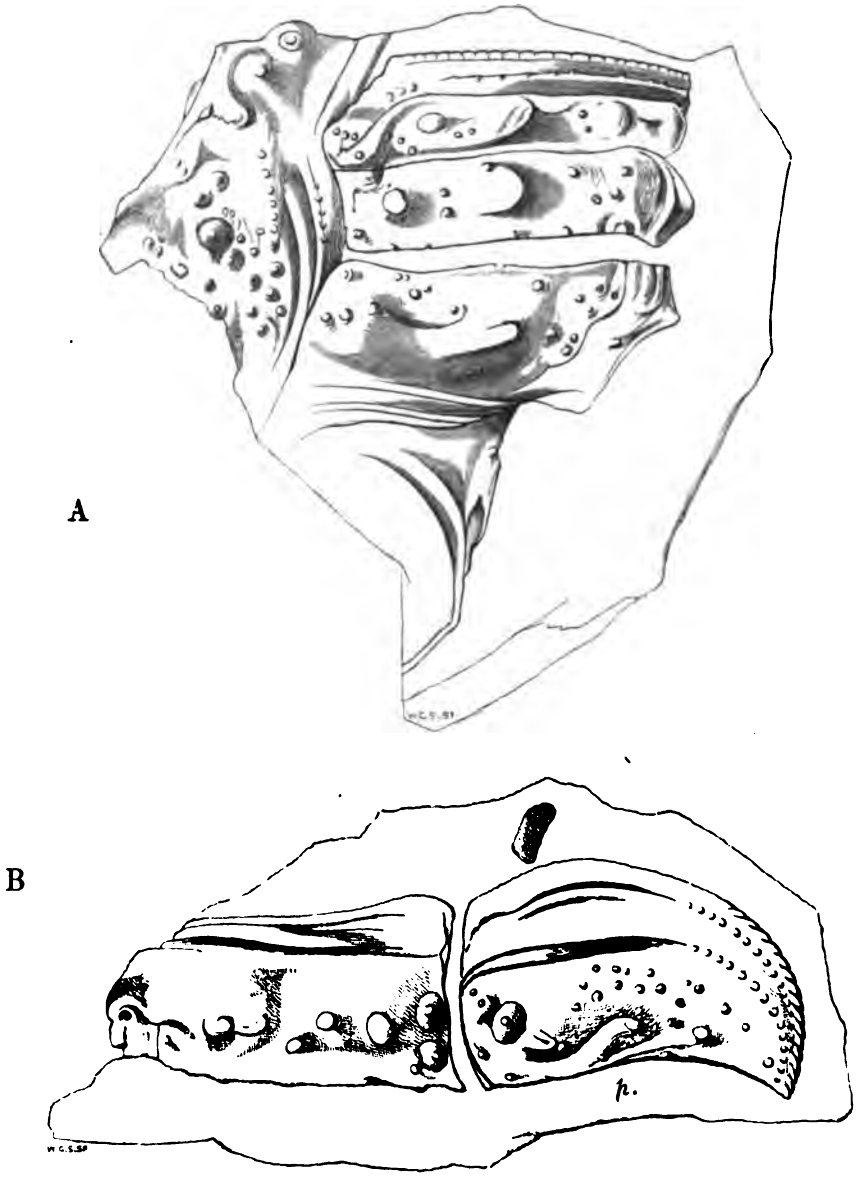

Fig. 55.—*Arthropleura armata,* Jordan.
Coal-measures, Saarbruck, Rhenish Prussia. See 'Palæontographica,' 1856, Band iv, taf. 2, figs. 4 and 5.

by me *Præarcturus gigas,* from the Old Red Sandstone of Herefordshire),[2] it seems highly probable that this fragment has no affinity with *Eurypterus* at all.

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[1] See below, page 126, and Pl. XXII and XXIII.

[2] 'Trans. Woolhope Naturalists' Field Club,' 1870, p. 266; 'Fossil Sketches,' No. 9, figs. 1 and 2, and No. 10.

With regard to the remaining fragments referred by Mr. Salter to *Eurypterus mammatus* (see Pl. XXIV, figs. 4, 5, 6), I am in no little difficulty; for here again Mr. Salter's description is borne out by his woodcut figures, but not by the specimens.

For instance, he speaks of the peculiar "tear-drop" ornamentation along the hinder margin of the segments, such as is seen in certain other fragments referred to *Eurypterus* (see Pl. XXVIII, figs. 16, 17, and 17 *a*). But in figs. 4, 5, and 6, these are really *cracks* in the tissue, as correctly represented on our plate by Mr. Griesbach, and not raised tubercular ornamentations thereon, as seen in the woodcut, p. 84 (figs. 4, 6, and 7). Mr. Salter himself says:

"The remaining pieces are evidently parts of a great Crustacean, and almost certainly belong to this one, for they have the same ornaments on the hinder edge; but they differ remarkably by having a curious set of short, wavy, interrupted ridges (or furrows, it is impossible to say which) lying transversely to the length, and which are equally distributed over the whole segment. They are not all of the same size, small rounded ridges being mixed with those of a more linear shape."

I carefully studied these fragments, and also submitted them to the examination of my colleague, Mr. William Carruthers, F.R.S., who has devoted himself specially to the study of fossil plant-remains, hoping that he would accept them as parts of some plant, like *Calamites* or *Knorria;* but for some time he was unable to do so. I was therefore obliged to treat them as animal, and probably Crustacean, although I could not compare them (like figs. 2 and 3) with any other form belonging to the order; for the scale-like ornamentation so characteristic of *Pterygotus* and *Eurypterus* is altogether wanting, nor could I detect any evidence of spines such as are preserved on fig. 2.

Fortunately at this juncture a portion of an undoubted plant-stem from the Ironstone of the English Coal-measures, which Mr. Carruthers had laid aside for examination, turned up, and furnished evidence of markings *identical* with those exhibited on figs. 4, 5, and 6 of Pl. XXIV, so that there is no longer any reason to doubt their vegetable origin. Mr. Carruthers has very kindly drawn up the subjoined account of these remains, which may now be considered as disposed of in a satisfactory manner.

The remaining specimens (figs. 2 and 3, Pl. XXIV) will be retained to represent Mr. Salter's species, which we refer provisionally to M. Jordan's genus as *Arthropleura mammata,* Salter, sp., about the affinities of which we cannot at present speak with any degree of certainty.[1]

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[1] Just as this sheet was passing through the press I received two additional contributions to Salter's *Eurypterus* (*Arthropleura*) *mammatus.* The first is a very curious compressed fragment of what appears to be the sternum of the thorax of a *Brachyurous Decapod* from the Coal-measures near Manchester, sent me for examination by W. Johnston Sollas, Esq., of St John's College, Cambridge.

The other consists of three tuberculated epimeral pieces so exactly resembling that marked *p* in our fig. B, Woodcut 55, p. 166, that, except for the variation in the wart-like tubercles, two of them might at once be mistaken for Jordan's type. There is the same deep groove in each, the same falcate border, the same admixture of large and small tubercles upon its surface occupying relatively the same positions. The

Formation.—Coal-measures. In the "Ferny Metal" beneath the "Seven-foot Coal" or "Ram's Mine."

Locality.—Pendleton Colliery, near Manchester.

The specimens are preserved in the Museum of Practical and Economic Geology, Jermyn Street.

NOTE ON SOME SUPPOSED FRAGMENTS OF A *EURYPTERUS.*

By W. Carruthers, Esq., F.R.S., &c., &c.

(Communicated to the Author.)

The specimens figured and described by the late Mr. Salter as portions of a *Eurypterus*, regarding which you have expressed to me doubts, are certainly fragments of a large Equisetaceous plant. They are very different in their general aspect from the common *Calamites* of the Coal-measures, and belong to a group of plants whose known remains are very fragmentary, and about the precise nature and affinities of which there has been considerable difference of opinion.

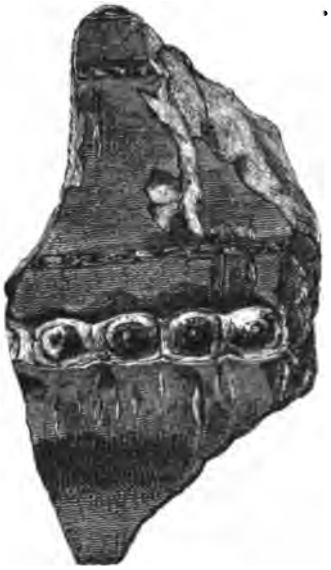

Fig. 56.—*Phytolithus parmatus*, Steinh. *Ulodendron parmatum*, Carr, Coal Measures, reduced ⅓ natural size.

In the British Museum there is a fragment of this plant showing portions of four joints of the stem (Fig. 56); two of these joints exhibit the oblong scars of the leaves, and a third has a series of large round scars, which have been produced by a whorl of axillary appendages. The surface of the stem is smooth, and immediately below the large round scars there are a number of cracks, through which the mud filling the medullary cavity has been pushed. In form and position these exactly agree with the "tear-drop" ornaments on Mr. Salter's fragments (see Fig. 56).

The counterpart of this specimen was figured by the Rev. H. Steinhauer, in his very valuable paper on "British Fossil Plants," published in the 'Transactions of the American Philosophical Society' (vol. i, new series, p. 286, pl. vi, fig. 1). This remarkably acute observer, however, referred it to his *Phytolithus parmatus* (*Ulodendron parmatum*, Carr.).

third specimen is more waved along its anterior curved border, and the hinder border is straighter than in Jordan's figure. These are from the roof-shale of "Top Little Vein" Camerton Collieries, near Bath, and were obtained by W. G. M'Murtrie, Esq., of Camerton, who has paid much attention to the Geology and Palæontology of this interesting district.

Both the Manchester and the Camerton specimens are from Plant-beds, and are associated with remains of *Neuropteris*, *Pecopteris*, &c. I have thought it proper to notice these remains here, but as they are not referable to the Eurypterida I shall figure and describe them at more detail elsewhere. They deserve, however, a passing notice in connection with the history of Mr. Salter's *Eurypterus mammatus*.

Lindley and Hutton met with a less perfect fragment, showing four of the large round scars (' Fossil Flora,' pl. cxxx); unable to determine anything as to the affinities of this fossil, they were satisfied with attaching to it a new generic name—*Cyclocladia*—and leaving their successors to throw some light on it when better materials should turn up.

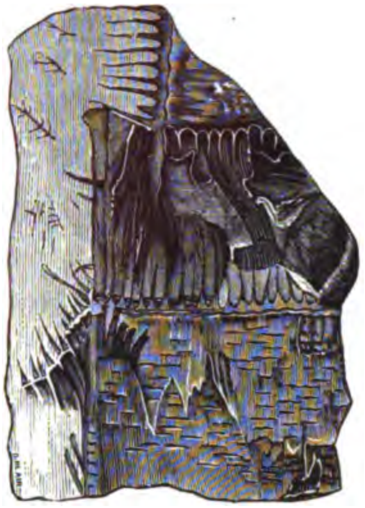

Fig. 57.—*Hippurites gigantea*, Lindl. Coal-measures, Newcastle-on-Tyne. (Lindl. & Hutt., pl. 114, ½ nat. size.)

They had, however, already published the portion of a stem with leaves belonging to the same plant under the name of *Hippurites gigantea* (' Fossil Flora,' pl. cxiv). This represents parts of three joints, two of them very obscure, from the way in which the specimen was broken, and the broken pieces pressed upon each other in the bed in which they were preserved. The surface of the stem, Lindley says, is in some places perfectly smooth, without the slightest trace of furrows or scars, but in other places it presents the appearance of transverse wrinkles. These transverse markings are shown on the lower joint (Fig. 57), and are obviously the same as the short, wavy, interrupted ridges lying transversely to the length, described and figured by Mr. Salter. The leaves occupy their natural position; they are acicular, somewhat dilated downwards, and united at the base, but not so as to form a sheath. There are indications of a central rib to the leaf. In a second species from the Forest of Dean (*H. longifolia*, Lindl. and Hutt., ' Fossil Flora,' pl. cxc) the long leaves are more obviously free to the very base.

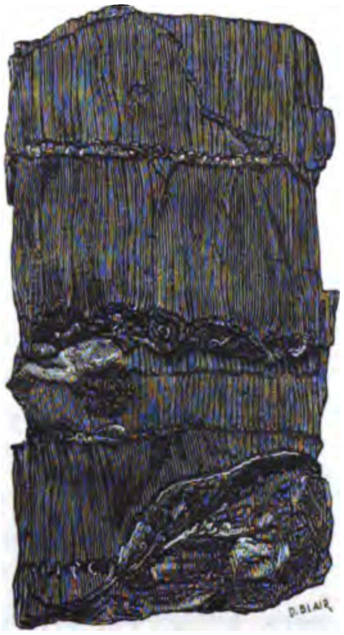

Fig. 58.—*Calamites varians*, Sternb. Coal-measures. (Germar, l. c., pl. xx, fig. 1, ½ nat. size.)

Germar has figured a larger specimen under the name of *Calamites varians*, Sternb. (' Steinkohlen v. Wettin und Löbejün,' p. 47, pl. xx, fig. 1), in which the scars of the leaves and of the axillary appendages are shown on the same specimen, as well as the furrowed structure of the interior so characteristic of Calamitean stems. (See Woodcut, Fig. 58.)

The very thin layer of coal which here represents the cylinder of the hollow stem, shows that this cylinder was very slender. This is obvious also from the cracks in Fig. 56, and the scarcely increased thickness from the overlying portions of the upper joint of Fig. 57. The perfectly smooth outer surface of the stem is also well shown in this specimen. The slender nature of the stem and the delicate transverse wrinkles resulting from this are very well shown by Ettingshausen in his memoir on *Calamites* (' Sitzungsbericht d. math.-natur. Class. d. K. Akad. Wissensch.,' vol. ix, pl. ii, fig. 1); and the tear-drop ornamentation is represented in the figure on pl. i, fig. i.

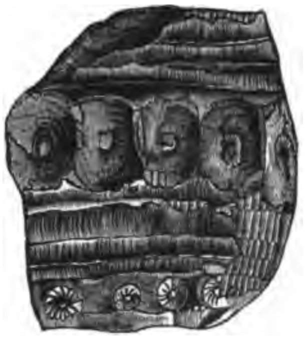

Fig. 59.—*Equisetites infundibuliformis*, Bronn, Coal-measures, Zwickau. (Geinitz, 'Steink. in Sachsen,' pl. x, f. 4, ½ nat. size.)

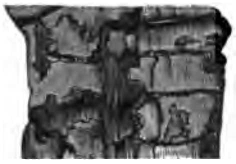

Fig. 60.—*Equisetites infundibuliformis*, Bronn, part of stem with verticils of leaf-scars, Coal-measures Zwickau. (Geinitz, op. cit., pl. x, f. 5 in part, ½ nat. size.

Geinitz, in his beautiful work 'On the Coal Formation in Saxony,' has added considerably to our knowledge of this set of Equisetacean stems. He figures a portion consisting of several joints, two of which are furnished with verticils of large scars, and a larger and more slender specimen with many joints (a portion of which is reproduced, Fig. 60) shows the position of the two sets of scars as in Steinhauer's specimen, as well as the ridges of the inner surface. The aspect of the larger upper whorl of scars in Fig. 59, and the character of the furrowing of the medullary cavity shown in Fig. 58 from Germar, seem to justify Geinitz in referring to this plant the *Calamites verticillatus*, Lindl. and Hutt., 'Fossil Flora,' pl. cxxxix. That these scars may have been produced by the cones, as held by Geinitz, I cannot doubt, but the specimen of *Hippurites longifolia*, Lindl. and Hutt., figured in 'Fossil Flora,' pl. cxc, shows that they were produced also by the ordinary leaf-bearing branches. The drawing of *Asterophyllites grandis*, Lindl. and Hutt., 'Fossil Flora,' pl. xvii, further corroborates this view.

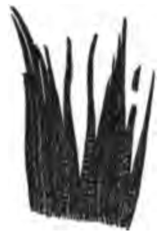

Fig. 61.—Foliage of *Equisetites infundibuliformis*, Bronn. Coal-measures, Zwickau. (Geinitz, op. cit., pl. x, f. 8 in part, ½ nat. size.)

Geinitz also figures the leaves, which agree in their general character with those of *Hippurites gigantea*, Lindl. and Hutt. Geinitz correlates with this plant a large cylindrical fruit, with a short, thick, and slightly curved base; and he believes that the larger scars are the impressions of the articulations of these cones. One of these scars is shown on fig. 6 of Salter's illustrations.[1] Schimper does not think it possible that this fruit, his *Macrostachya infundibuliformis*, can belong to Geinitz's plant, but I see no reason for doubting it. The Calamitean plants of the Coal-measures are so fragmentary that it is very difficult to correlate the different parts; and this difficulty is vastly increased from the immense numbers of worthless "species" that exist, based, in the infancy of our knowledge, on characters then supposed to be important, but which are now known to be of no value. Nevertheless these very characters are, up to the present time, being employed to burthen our pages with synonyms. Schimper reduces the whole of the true Calamites to seven satisfactory and nine unsatisfactory species. I would not hesitate to go yet a little further with Ettingshausen, though perhaps his wholesale demolition of supposed species is somewhat too thorough; and I cannot, at any rate, defend his placing the plant we are now dealing with among the crowd which compose his *Calamites communis*. Of course, if Geinitz is right in his correlation of the fruit, Ettingshausen himself would eliminate it from the synonyms; but even apart from this, it seems to me that the delicate stem made up of a large series of very small vascular ridges with intervening cellular structures, and the form of the persistent leaves sufficiently separate them from what we know as the ordinary type of Calamite in this country as to make a good generic distinction, and to justify Lindley and Hutton in their placing them in a distinct genus. Their name (*Hippurites*), however, indicates a false affinity, and must be set aside for Sternberg's *Equisetites*, unnecessarily altered by Schimper into *Equisetides*. Probably the "thin-walled *Calamopitus*," figured by Prof. Williamson in his recent memoir on "Calamites" ('Phil. Trans.,' 1871, pl. xxv, figs. 19, 20), belongs to this plant; and the Calamitean strobilus which he has so well worked out in the 'Memoirs of the Literary and Philosophical Society of Manchester,' vol. iv, p. 248, may be the fruit.

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[1] See Woodcut, Fig. 54, 6, p. 164; also the accompanying Pl. XXIV, fig. 4.

"*EURYPTERUS? (EUPHOBERIA) FEROX:*"—*Salter*.

EURYPTERUS ? (ARTHROPLEURA) FEROX, *Salter*. Quart. Journ. Geol. Soc., 1863, vol. xix, p. 86, woodcut, fig. 8.

CATERPILLAR ?, *J. O. Westwood*, in Brodie's Fossil Insects in the Secondary Rocks of England, 1845, p. xvii, p. 115, pl. i, fig. 11.

Accompanying Mr. Salter's description of *Eurypterus* (*Arthropleura ?*) *mammatus*[1] is a notice of another form named by him *Eurypterus ?* (*Arthropleura*) *ferox*. The specimen described forms Fig. 54, 8, of the Woodcut reproduced at p. 164 from Mr. Salter's paper, and was obtained by Mr. Charles Ketley (of Smethwick) from the Clay-ironstone nodules in the shale over the "Thick Coal" of the Coal-measures, Tipton, Staffordshire, associated with abundance of fossil plants.

Mr. Salter observes, "At first sight it would strike an entomologist as a fossil Caterpillar of the *Saturnia* genus, so strong is its resemblance in size, form, and ornament to the larvæ of that group. Unlike most Crustaceans from the old rocks, it is extravagantly ornamented with long forked spines." Such spines are found on the carapace of *Lithodes*, and also on the segments of the abdomen of the "Murray River Cray-fish," *Potamobius astacus*.

Mr. Salter considers von Meyer's *Arthropleura armata* (already referred to) to belong to *Eurypterus* (see Woodcut, Fig. 55, p. 166), and thinks it possible to assign both his *E. mammatus* and *E. ferox* to the same group.

In a 'History of Fossil Insects of the Secondary Rocks of England,' by the Rev. P. B. Brodie, M.A., F.G.S., 8vo, published in 1845, some specimens are figured from the collection of the Rev. F. W. Hope,[2] now preserved in the Oxford Museum.

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[1] 'Quart. Journ. Geol. Soc.,' vol. xix, p. 86. See also Woodcut, Fig. 54, 8, p. 164.

[2] The Founder of the Hope Professorship of Zoology in the University of Oxford, so ably filled by Prof. J. O. Westwood, M.A., F.L.S., the eminent Entomologist and Carcinologist.

Among others is a specimen "from Coalbrook Dale, which has very much the appearance of some large Caterpillar, furnished with rows of tubercles, to which setæ or bristles were attached, as in the case of the Caterpillar of our common English Emperor Moth (*Saturnia Pavonia minor*): unfortunately the specimen is imperfect at each end, and therefore it is impossible to judge of the appendages of the head or tail. It will be seen that there appear to be distensions of the membrane connecting several of the segments of the body together, as between the first and second, second and third, fourth and fifth (on the right hand side), and seventh and eighth. Now this could not, I think, occur to so visible an extent in a Lepidopterous larva, because it seems to intimate that the broader parts of the body (or the true segments) are of a firmer texture than the connecting distendable membrane. The lateral series of long, slender, and *evidently articulated* appendages seem also to throw a doubt on the Insect being a Lepidopterous larva. These appendages have some remote analogy to those of a portion of the segments of *Squilla*, but this is only in appearance, and not a real relationship. The dark line which runs down the back seems quite analogous to the great dorsal vessel or heart of the Caterpillars. ("Introductory Observations," by J. O. Westwood,[1] M.A., F.L.S., &c., &c.). See Woodcut, Fig. 63.

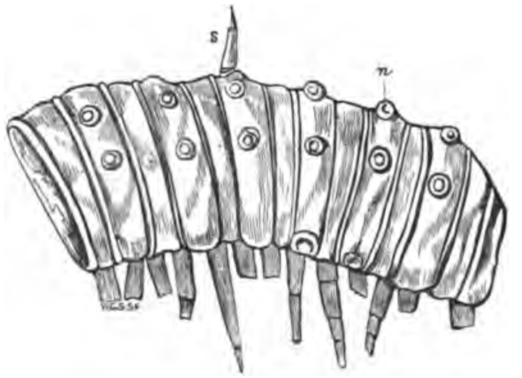

FIG. 62.—*Euphoberia ? major*, M. & W., Coal-measures, Grundy Co., Illinois, U.S.A. See Messrs. Meek and Worthen's 'Palæontology of Illinois,' 1868, vol. iii, p. 558. One dorsal spine (*s*) still remains *in sitû*; the nodes (*n*) are evidently the bases of spine. Several pairs of the legs are seen below.

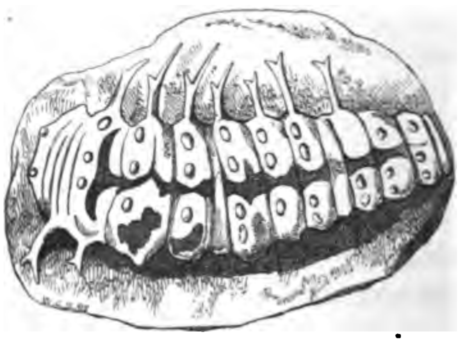

FIG. 63.—*Arthropleura ferox*, Salter, specimen figured by the Rev. P. B. Brodie, preserved in the Hope Collection, Oxford, from the Coal-measures, Coalbrookdale. [Copied from Plate I, fig. 11, of Brodie's 'Fossil Insects.']

Among the numerous interesting remains of Arthropoda from the Coal-measures of Illinois, figured and described by Messrs. F. B. Meek and A. H. Worthen, in the Palæontology of Illinois, published in vol. iii of the publications of the Geological Survey of Illinois (1868), is a specimen which there can be little doubt is identical with that figured and described by Mr. Salter as *Eurypterus ? ferox*, and by Mr. Westwood as the "larva of some unknown insect." See Woodcut, Fig. 62.

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[1] In Brodie's 'Fossil Insects of the Secondary Rocks,' p. xviii.

Messrs. Meek and Worthen provisionally refer their specimen to the Myriapoda and to their genus *Euphoberia*, under the name of *Euphoberia ? major*, M. and W.

A smaller species of *Euphoberia*, also armed with forked spines, named *E. armigera*, was found in the Coal-measures of Grundy, County Illinois, and is described in the same work by Messrs. Meek and Worthen. A specimen equalling in size their *E. armigera* was figured and described by the writer in the 'Geological Magazine,', 1871, vol. viii (pl. iii, fig. 6, p. 97), from the Coal-measures near Glasgow, under the name of *E. Brownii.*

Messrs. Meek and Worthen write as follows respecting their specimen of *Euphoberia ? major* (see Woodcut, Fig. 62):

"We unfortunately yet know it only from fragments, one of the best of which is represented by the annexed cut. If as long in proportion as the other species, it probably attained a length of twelve to fifteen inches, and must have presented a formidable appearance. The node-like prominences marked *n* in the figure are evidently the bases of spines that have been broken away. One of these, however, is seen lying in the matrix at the point marked *s*. Another specimen shows a direct view of the dorsal side compressed flat. In this traces of two rows of these node-like prominences are seen along the middle, while a row of spines can be seen projecting out into the matrix on each side. This latter specimen so nearly resembles a fossil figured by Mr. Salter, in the 'Quarterly Journal of the Geological Society of London,' vol. xix, p. 84, fig. 8, from the Staffordshire Coal-measures, under the name of *Eurypterus* (*Arthropleura*) *ferox*, that we can scarcely entertain a doubt that they are congeneric. Indeed if it were not for the fact that the species *ferox* has its spines provided with three instead of two prongs, we would even suspect that our specimens might possibly belong to the same species.

"Mr. Salter thought his specimen probably a part of the central lobe of a trilobate *Eurypterus* or some allied genus, an opinion he would not have entertained for a moment (provided we are right in our suggestion respecting its relations to our fossil), if he had seen a specimen showing a side-view of even a few of the segments with their legs attached. At any rate our fossil is certainly distinct from the genus *Arthropleura* of Jordan and Von Meyer, which is almost beyond doubt a Crustacean."[1]

After carefully examining the English *E. ferox* of Mr. Salter, and comparing it with Messrs. Meek and Worthen's figure and description, I am disposed fully to agree with the latter writers, and to refer it to the Myriapoda and to their genus *Euphoberia*, feeling certain that it has no relation whatever with *Eurypterus.*

Having in the first part of this Monograph placed *E. ferox* in the list of species given on p. 15, it seemed desirable to show the reason why it should no longer be so retained

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[1] Op. cit., p. 558.

in our classification. The reasons may briefly be stated:—(1) We know of no undoubted *Eurypterus* with body-segments ornamented with spines or tubercles like those of *E. ferox*. (2) The segments, when seen in series, are never (in *Eurypterus*) of a uniform size, but invariably diminish, as regards their breadth, from the seventh segment towards the telson. With the single exception of *Eurypterus Scouleri* (a most aberrant form of the *Eurypteria*), all the members have the segments but very slightly arched, and (save in the three most posterior segments) always much broader than long.

We may therefore consider Mr. Salter's *Eurypterus ? ferox* as excluded from the genus *Eurypterus*, and also from Jordan's genus *Arthropleura*, and may refer it with considerable confidence to Messrs. Meek and Worthen's Myriapodous genus *Euphoberia*.

Formation.—Coal-measures. Clay-ironstone.

Localities.—Coalbroak Dale, Shropshire; Tipton, Staffordshire.

Foreign Localities.—Coal-measures, Grundy, County Illinois, U.S. America.

Genus 5.—HEMIASPIS:—*H. Woodw.* 1865.

Species 1.—HEMIASPIS LIMULOIDES:—*H. Woodw.* Pl. XXX, figs. 1, 2.

HEMIASPIS LIMULOIDES, *H. Woodward.* Brit. Assoc. Report, Bath Meeting, 1864, Section C.

— — *H. Woodward.* Quart. Journ. Geol. Soc., 1864, vol. xxi, p. 490, pl. xiv, figs. 7*a*, 7*c*.

When I first drew attention to this genus at the Bath Meeting of the British Association in 1864, only one nearly perfect specimen was known.

Mr. Salter was acquainted with it, however, so long ago as 1857, and referred to this individual, among other new and undescribed Crustacea, in a paper "On some New Palæozoic Star-fishes" found at Leintwardine, Shropshire,[1] under the name of *Limuloides*.

Portions of several others had also been met with, to which Mr. Salter attached MS. names in the Museum of Practical Geology, Jermyn Street, but they have not been heretofore described.

The most perfect of these Limuloid forms was described by me in a paper read before the Geological Society in June, 1865.[2]

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[1] See 'Ann. and Mag. Nat. Hist.,' 2nd series, 1857, vol. xx, p. 321.

[2] See 'Quart. Journ. Geol. Soc.,' 1865, vol. xxi, p. 490, pl. xiv, fig. 7.

Since that date other fragments have been obtained, and also another nearly perfect example (obtained by the late Mr. Henry Wyatt-Edgell) of the species named by me *Hemiaspis limuloides*, which, having the upper central portion of the carapace preserved, nearly completes our knowledge of this species.

The great interest attaching to this form arises from the fact that it offers just the desiderated link by which to connect the *Xiphosura* with the *Eurypterida*.

Limuli, apparently differing but little as regards their carapace from the recent species now found living on the Coasts of China, Japan, and the north-east coast of North America, occur as early as the deposition of the Solenhofen Limestone of Bavaria; and in the Coal-measures of England and Ireland several species of *Bellinuri* and *Prestwichiæ* occur, in which the cephalic shield is composed of the cephalothorax; and the segments of the abdomen, if not anchylosed in all, are so in most.

But in the specimen under consideration we have the cephalic, thoracic, and abdominal divisions still remaining distinct, and apparently capable of separate flexure. This important character at once separates it from *Limulus*, *Bellinurus*, and *Prestwichia*.

I did not on this account (*with the concurrence of Mr. Salter* given at the time) use his MS. name of *Limuloides* as a generic appellation, but proposed the name *Hemiaspis* (from ἥμισυς, *half*, and ἀσπὶς, *a shield*), reserving Mr. Salter's MS. name *Limuloides* for the specific title of the most perfect species of the genus (see Pl. XXX, figs. 1, 2).

But it will be observed that *Hemiaspis* is also, *in general appearance*, strongly severed from the other species of Eurypterida, as well as from the Xiphosura, in structure.

The three divisions into head, thorax, and abdomen are more strongly marked. The abdomen is reduced to very slender proportions, less than one third the length of the animal (the entire specimen measuring 2½ inches in length by one inch in width.

The carapace in general outline resembles *Limulus*, but is more dilated laterally. There is a small stellate ornamentation in the centre of each cheek, having five to six rays, and measuring about a line in extent; but whether this represents the position of the eyes I am quite unable to say. It is so unlike the eye of any other member of the group, that I am inclined to doubt its relation to that organ. It seems probable that the eyes were placed along the lateral margin of the glabella, not upon the centre of the cheek.

There is a faint indication on one side of fig. 1 and on fig. 2 of a facial suture to the head-shield (as in the Trilobites), with a small aperture upon its border, which may possibly indicate the true position of the eye, but it is by no means clearly defined.

The surface of the glabella when perfect (as shown in our Plate XXX, fig. 2) appears to have been almost smooth,[1] save that it is traversed by two ridges which, commencing as raised tubercles on the posterior border of the head-shield, three lines apart, gradually converge and unite, so as to form an arch, the summit of which nearly touches the front border of the glabella.

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[1] In the original description of the glabella of *Hemiaspis limuloides* (see 'Quart. Journ. Geol. Soc.,' vol. xxi, p. 490) I have described the glabella, *from a detached portion*, as "ornamented with a semicircle of nine tubercles, and a tenth immediately within the circle upon the elevated front, and two small tubercles at the posterior margin." The acquisition of the second specimen (fig. 2, pl. xxx) proves this fragment to belong to another species, not to *H. limuloides*, as formerly supposed.

Nine ray-like corrugations descend from the glabella towards the margin of the shield, and the whole surface of the carapace is very minutely granulated. The lateral margins of the shield are ornamented with minute spines, and the rounded posterior angles of the carapace terminate in a broad triangular point directed backwards. A fringe of lesser spines arms the lateral border of the glabella.

The thorax is composed of six strongly trilobed plates; the epimera being equal in breadth to the central portion of each segment.

The first segment is the largest, being 1 line in depth and 7½ in breadth, including the epimera, which are pointed at their extremities and slightly overlap the following segment. The four following segments have the borders of their epimeral pieces rounded, and gradually decrease in breadth downwards from 9 lines to 7, and increase in depth from ½ line to 1 line.

A section of one of the segments would present an outline like that of *Phacops* among the Trilobites, namely, a triple corrugation.

The sixth thoracic segment is more strongly arched than the preceding ones, and the lateral borders are divided into two rounded lobes on each side: breadth 5 lines, depth 1 line.

The abdomen consists of only three segments each, 2 lines in breadth and 1½ lines in depth. The first has no epimera, and appears to move freely at its articulation with the six thoracic segment. The second and third segments have small epimeral pieces, which are bilobed, with the posterior lobe more pointed. A line of small tubercles runs down the centre of these three joints, which are somewhat raised at their articular borders.

The telson is 12 lines in length and 1¼ line in breadth where it articulates with the abdomen. It tapers gradually to a fine point.

If we regard the first six body-rings from the head as thoracic, and the remaining three segments as abdominal, we must presume that each of these latter is a double segment, as compared with the segments of the *Eurypterida* proper.

On the other hand, the presence of these three segments precludes our considering the head to be the cephalothorax and the succeeding segments the abdomen, a view controverted by me in my examination of the structure of the *Xiphosura*.[1]

The smallness of the abdomen, and its reduction from the assumed normal number of six to three, seems to indicate a form by which, with the help of others, we may bridge over the interval that has hitherto existed between these two groups, the *Eurypterida* and the *Xiphosura*.

Although *Hemiaspis* is the only genus met with in Britain having this remarkable form, we know of three Russian genera which present almost identical peculiarities of structure. Dr. J. Nieszkowski has described two forms from the Upper Silurian of the Island of Oesel, namely, *Pseudoniscus aculeatus* (Woodcut, Fig. 65), and *Exapinurus Schrenkii* (Woodcut, Fig. 66); and Dr. d'Eichwald has described a third form under the title of *Bunodes lunula* (Woodcut, Fig. 67), from the same rich locality and formation.[1]

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[1] See paper by the author, 'Quart. Journ. Geol. Soc.,' 1867, vol. xxiii, p, 28, pl. i and ii.

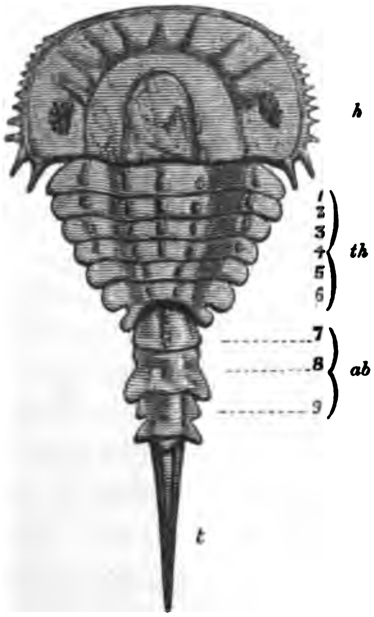

Fig. 64.—***Hemiaspis limuloides*, H. Woodward, Lower Ludlow, Leintwardine.**

***h*, the head; *th*, the six thoracic segments; *ab*, the three abdominal somites; *t*, the telson.**

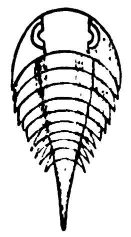

Fig. 65.—*Pseudoniscus aculeatus*, Nieszk., Upper Silurian, Isle of Oesel, Baltic.

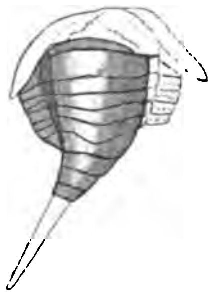

Fig. 66.—*Exapinurus Schrenkii*, Nieszk., U. Silurian, I. of Oesel, Baltic.

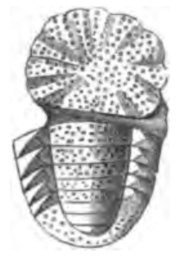

Fig. 67.—*Bunodes lunula*,[2] Eichw., U. Silurian, I. of Oesel, Baltic.

All these forms have the three well-marked divisions to their bodies into head, thorax, and abdomen, and all, save *Bunodes*, possessed a telson, or tail-spine, and free articulated thoracic somites.

In addition to *Hemiaspis limuloides*, already described, there are certain other specimens in the Museum of Practical Geology, to which Mr. Salter has appended MS. names, namely—

Hemiaspis (*Limuloides*) *speratus*, Salter MS.
,, ,, *optatus*, ,,
,, ,, *tuberculatus*, ,,

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[1] 'Archiv für die Naturk. Liv- Ehst- und Kurlands,' erste Series, vol. ii, pl. ii, figs. 12, 13, and 15, pp. 378—382, Dorpat, 1859, 8vo.

[2] It is just possible that *Bunodes* may prove to be an Arachnid related to Scudder's *Architarbus rotundatus* from Illinois, U.S.

In Lowry's Chart of the Genera of Fossil Crustacea designed by Mr. J. W. Salter and myself, Mr. Salter has figured a head-shield of *Hemiaspis* under the name of *H. Salweyi*. There can be no doubt that this form is identical with *Limuloides tuberculatus* of Salter. I consider his *Limuloides speratus* and *L. optatus* to represent but one species, closely allied to *H. limuloides*. A portion of the head-shield of another form distinct from the foregoing, from the Wenlock Shale, Dudley, completes the known species of *Hemiaspis*. *Formation and Locality.*—Lower Ludlow; Leintwardine.

Species 2.—HEMIASPIS SPERATUS:—H. Woodw. Pl. XXX, figs. 5 and 7.

Limuloides speratus, *Salter*, MS.
— optatus, *Salter*, MS.

This species is represented by four head-shields only; body-segments are not known.

It is no doubt closely related to *H. limuloides* already described, but the carapace is broader in proportion to its length, and the radiating lines or ridges which in that species take their rise around the margin of a well-defined central glabella, in *H. speratus* extend over the whole surface, save a small quadrate area at the centre of the posterior border. From this small area seven diverging costæ are given off; the three in front being nearly equidistant and straight, the two next, which rise from the outer angles of the central area, divide and form a Y-shaped ridge on each latero-anterior border; the two most posterior costæ curve upwards and outwards from the posterior border of the glabella to the lateral margins of the shield, and are marked midway by a minute lenticular space which probably indicates the position of the eye (see Fig. 68, *e*).

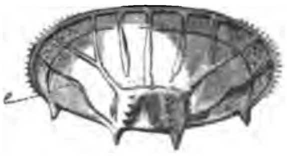

Fig. 68.—Head-shield of *Hemiaspis speratus*, Salter, MS. Nat. size. (Restored.) *e.* position of the eye ?

The head-shield is broadly arcuate in front, and the margin, especially on the cheeks, is fringed with a closely set row of minute spines; the lateral angles of the shield are truncated not produced posteriorly; the hinder border of the head-shield is armed with four equidistant spines. The surface of the carapace, especially around the border, is covered with a very minute granular ornamentation. The following measurements show the relative size of the head-shields of *Hemiaspis speratus*:

Breadth.	Length.	
15 lines	7½ lines	(Pl. XXX, fig. 7), Mus. Brit.
10½ ,,	6 ,,	(,, ,, 5), ,,
13 ,,	8½ ,,	(Woodcut, Fig. 68.) Mus. Pract. Geol.
11½ ,,	9 ,,	,,

Formation and Locality.—This species is found in the Lower Ludlow Rock of Leintwardine, and is represented by specimens of the head only, preserved in the British Museum, and in the Museum of Practical Geology, Jermyn Street.

Species 3.—HEMIASPIS HORRIDUS:—H. Woodw. Pl. XXX, fig. 6.

This species represented by a single example obtained by Charles Ketley, Esq., from the Tunnel shale, Dudley, and now preserved in the British Museum is the oldest example in time of this curious genus.

When entire the carapace must have measured 1¼ inch in breadth by 8 lines in length; the edge is thickly set with prominent sharp-pointed spines ½ a line to a line in length, whilst two strongly marked spines, 2 lines in length, project from each posterior angle of the carapace; the spines along the hinder border of the shield, if present in this species, are not preserved in this example. The median line of the carapace, which is slightly tumid, is marked by one rounded and prominent tubercle and two elongated confluent ones, whilst on either side of this median line three other divergent lines of elongated tubercles arise and radiate outwards to the border of the shield. The surface of the carapace between the tubercles is finely granulated, with here and there a slightly larger pimple upon its surface. Eyes not visible.

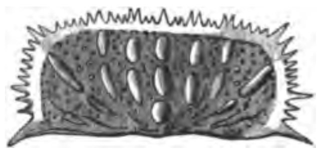
Fig. 69.—Head-shield of *Hemiaspis horridus*, H. Woodward. (Restored.) Wenlock shale, Tunnel, Dudley.

There are some other fragments which may indicate another species (see Pl. XXX, fig. 3), but they are too fragmentary for determination; and I therefore think it best merely to notice them in passing.

Formation and Locality.—Wenlock shale, Dudley. The specimen is in the British Museum.

Species 4.—HEMIASPIS SALWEYI:—Salter. Pl. XXX, fig. 4.

Limuloides tuberculatus, *Salter*, MS. (Mus. Pract. Geol.).
Hemiaspis Salweyi, *Salter*. Lowry's Chart of Fossil Crustacea; Eurypterida, Fig. 3, 1865.

This species is represented by two head-shields only; the body-segments, as with the preceding species, are not preserved. The carapace, which is very tumid, is nearly circular in outline, and measures 1½ inches in breadth and 1 inch in length. The posterior border of the glabella is armed with two large spines, 3 lines in length and 4 lines apart, whilst three smaller ones, also directed backwards, are arranged on either side of the genal border. The surface of the carapace is covered with a minute granular ornamentation; the raised central portion is flanked by a border of somewhat elongated tubercles; within the central area are three or four ronuded tubercles arranged in two oblique rows about four lines apart, commencing on the posterior border of the head at the base of the two large spines. One central prominent tubercle and two lesser lateral ones on the front of the glabella, complete the ornamentation of the head-shield.

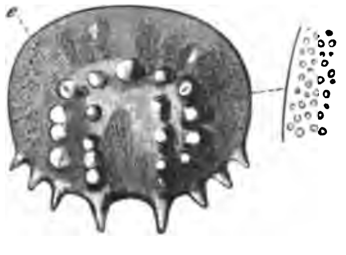
Fig. 70.—Head-shield of *Hemiaspis Salweyi*, Salter. (Restored.) U. Ludlow, near Ludlow.

The spot marked *e* on the annexed Woodcut (Fig. 70), near the latero-anterior border of the raised glabella, probably indicates the position of the eye. There is a slight indication of costæ on the front border of the head.

Formation and Locality.—Upper Ludlow, near Ludlow; Mus. Pract. Geology, Jermyn Street; Lower Ludlow, Ledbury; British Museum.

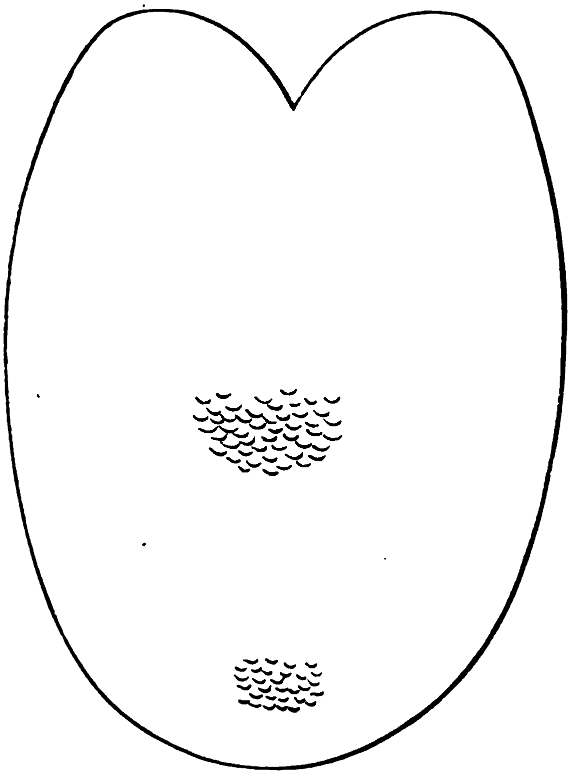

FIG. 71.—Lip-plate of *Pterygotus* from the Upper Silurian; Rootziküll, Isle of Oesel, Baltic; associated with *Pseudoniscus*, *Exapinurus*, and *Bunodes*.[1]

POSTSCRIPT.—After the foregoing pages had gone to press, Mr. James Armstrong, whilst visiting the British Museum, carefully examined the matrix in which the specimens of *Eurypterus Scouleri* are contained (figured on Plates XXV, XXVI, and XXVII, and stated to be from Burdie House, near Edinburgh), when he at once pronounced them to be from a quarry at Kirkton, near Bathgate, West Lothian; which is *not* in the Coal proper but in the Carboniferous Limestone. This bed also contains *Sphenopteris Hibberti* (described in vol. iii, p. 73, of Lindley and Hutton's 'Fossil Flora').

The Limestone is a freshwater deposit, and abounds in bands of silex alternating with calcareous matter, and presents all the appearance of having been deposited by thermal waters during the carboniferous epoch.—H. W.

BRITISH MUSEUM; *17th September*, 1872.

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[1] 'Archiv für die Naturk. Liv- Ehst- und Kurlands,' Dorpat, 1859, Series 1, vol. ii, p. 382, pl. i, fig. 19.

A MONOGRAPH

OF THE

BRITISH FOSSIL CRUSTACEA

OF THE

ORDER MEROSTOMATA.

PART V.

SUB-ORDER—XIPHOSURA, Gronovan.

INTRODUCTION.

IN the first part of this Monograph (p. 24) I have alluded to the proposal made by Professor McCoy, in 1849,[1] to unite in one tribe of the order ENTOMOSTRACA, the recent and fossil *Limulidæ*, and the extinct genera of *Pterygotus*, *Eurypterus*, &c.

This generalization, however, failed to meet with acceptance and adoption, having been founded upon an incorrect view of the structure of the fossil forms it associated together.[2] Nor can it be doubted that the arrangement was based on conjecture rather than upon a minute acquaintance with the anatomy of those extinct genera *Pterygotus* and *Eurypterus*, then only known in England by extremely fragmentary remains.[3]

In the important memoir by Messrs. Huxley and Salter, published in 1859, Professor Huxley thus expressed his views on the union of the two groups:

"The *Pœcilopoda* are, I believe, the only *Crustacea* which possess antennary organs like those of *Pterygotus*, and, like them, have the gnathites converted into locomotive organs, want the appendages to the sixth abdominal somite, and present on some parts of the body a remotely similar sculpture. In this order, however, we find but a small labrum—a rudimentary metastoma—a very differently constructed body, and a large number of appendages, both thoracic and abdominal, characters which effectually preclude the association of the extinct *Crustacea* under discussion with this type." He adds in a note: "If the abdominal somites of the Carboniferous *Bellinurus*, &c., were really free, they would present a certain approximation to the *Pterygoti*. Indeed, the evidence that these Carboniferous Crustacea were true *Pœcilopoda* is, to my mind, anything but conclusive" (op. cit., p. 34).

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[1] See 'Ann. and Mag. Nat. Hist.,' 2nd series (1849), vol. iv, p. 393, and Lyell's 'Manual,' 1855, 5th edition, p. 420.

[2] See Introduction to Huxley and Salter's 'Monograph on the Eurypteridæ,' 1859, p. 7, and H. Woodward's paper "On the Structure of the Xiphosura having reference to their Relationship with the Eurypterida," 'Quart. Journ. Geol. Soc.,' 1867, vol. xxiii, p. 28.

[3] See McCoy's restoration of *Pterygotus* (reproduced from Lyell's 'Manual'), Part I, p. 24, of this Monograph.

One serious difficulty in homologising the structures of *Limulus* and *Pterygotus*, which no doubt weighed strongly with Messrs. Huxley and Salter against the classification proposed by McCoy, arose from their having erroneously placed the large bilaterally symmetrical plate (which we now know to be the thoracic plate or operculum) on the front ventral surface of the head-shield, and named it "the conjoined metastoma and labrum."[1] This mistake was, however, pointed out and corrected later on in the same year (1859) by Professor James Hall, of Albany, U.S. (in his 'Palæontology of the State of New York'),[2] whose researches into the structure and affinities of *Eurypterus*, *Pterygotus*, and *Limulus*, have led him to the conclusion that a close relationship exists between them, and in this opinion he is supported by Professor Agassiz,[3] who believes them to belong even to the same order. "He regards the antennal system as entirely absent. The organs of locomotion belong to the cephalic region; and while externally they perform the functions of feet, they are, at the base, organs of manducation. The central organ indicated as a locomotive appendage[4] (by Hall), Professor Agassiz regards as similar to the appendage attached to the membranaceous feet, behind the swimming feet of *Limulus*, and instead of being double is anchylosed as in young *Limulus*."

Three years later I devoted much time to the examination of these forms, and without being aware of the already published views of Professors Hall and Agassiz, I arrived independently at the same conclusions with them. Fortunately, however, just as I was about to publish them in 1863,[5] I became aware of Professor Hall's observations, and was delighted to discover, that, if not the first to interpret the structure and affinities of these interesting forms, I had at least excellent confirmation as to the correctness of my views.

In the same year (1863) Mr. W. Hellier Baily, F.G.S., Acting Palæontologist to the Geological Survey of Ireland, published his "Remarks on some Coal-measure Crustacea belonging to the genus *Bellinurus*, König, with descriptions of two new species from Queen's County, Ireland."[1] Mr. Baily points out the importance of maintaining König's genus *Bellinurus*,[2] which had been set aside by Buckland, in his 'Bridgewater Treatise,' who referred this Coal-measure form to the modern genus *Limulus*.[3] He defines them as Entomostraca of the legion Pœcilopoda, and order Xiphosura. Mr. Baily also approves and cites Pictet's arrangement, who places *Limulus*, *Halycine*, *Bellinurus*, and *Pterygotus* in the order Xiphosura.[4]

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[1] See Mr. Salter's restoration of *Pterygotus anglicus*, made in 1859 for Murchison's 'Siluria,' and reproduced in Part I, p. 27, of this Monograph.

[2] Hall, 'Natural Hist. of New York: Palæontology' (1859), vol. iii, p. 393.

[3] Op. cit., p. 394.

[4] The median appendage of the thoracic plate or operculum.

[5] See article "On the 'Seraphim' (*Pterygotus anglicus*) and its Allies," by H. Woodward, in 'Intellectual Observer,' 1863, vol. iv, p. 229 (with a plate and a series of woodcuts).

In a communication to the Geological Society in 1866,[5] I have endeavoured to show the grounds upon which my classification of the Eurypterida and Xiphosura in the order Merostomata is based; and it may perhaps be desirable before proceeding with the descriptions of the genera and species belonging to the remaining sub-order, briefly to recapitulate the reasons for adopting and adhering to it.

The Sub-orders Eurypterida and Xiphosura compared.

I.—In the division of the Merostomata, already described, we have seen that in *Pterygotus* (Part I, Pl. VIII) and *Eurypterus* (Part IV, p. 132, woodcut, fig. 40) the animal consists of a more or less semicircular head-shield (*cephalon*, Bates;[6] *cephaletron*, Owen[7]), bearing in the centre the ocelli, and also a larger pair of marginal or subcentral compound eyes upon its dorsal aspect; whilst beneath, upon its ventral aspect, we find the oral aperture, in front of which arise a pair of chelate (in *Pterygotus*) or simple antennæ (in *Eurypterus*, *Slimonia*,[8] and *Stylonurus*[9]), followed by three pairs of more or less slender monodactylous pedipalps, and lastly, by a pair of very broad (spatulate) and powerful swimming-feet, whose basal joints subserve the office of mandibles and maxillæ.

The general arrangement of these oral appendages is alike in all the Eurypterida save that in *Pterygotus*, in which the antennæ are chelate (serving as powerful organs of prehension); the basal joint does not subserve the function of manducation, but in *Slimonia* (Part III, Pl XVII, fig. 3), *Stylonurus* (Part IV, p. 131, fig. 39), and *Eurypterus* (Part IV, p. 132, fig. 40), in which the antennæ are small and simple, the basal joints are always subservient to alimentation; whilst in *Stylonurus* two of the most posterior pairs of appendages fulfil the function of natation, being developed into long slender oars, which upon occasion might also have served as claspers by which to anchor itself to any floating body when resting or in quest of food.

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[1] See 'Ann. and Mag. Nat. Hist.,' 1863, 3rd series, vol. xi, p. 107, pl. v.

[2] König's 'Icones Fossilium Sectiles,' 1820, pl. xviii, fig. 230.

[3] Buckland's 'Bridgewater Treatise,' 1836, vol. i, p. 396, vol. ii, p. 77, pl. xlvi'', fig. 3.

[4] Pictet's 'Traité de Paléontologie,' ed. 2, 1854.

[5] See 'On some points in the Structure of the Xiphosura having reference to their Relationship with the Eurypterida,' by H. Woodward, 1876, vol. xxiii, p. 28, pls. i and ii (read November 21st, 1866).

[6] See Introduction, Part I, p. 5.

[7] See 'Anatomy of the American King-Crab (*Limulus polyphemus*),' 1873, by Prof. Owen, F.R.S., p. 463; 'Trans. Linnean Soc.,' vol. xxviii, part iii.

[8] See *ante*, Part III, p. 109, fig. 31.

[9] See *ante*, Part IV, p. 131, fig. 39.

Immediately behind the mouth and attached to the hinder portion of the head, with its free border extending forward so as to overlap the bases of the maxillipeds and the oral aperture, is the great metastoma or post-oral plate, which is present in all the EURYPTERIDA.

The compound head is succeeded by twelve free and movable segments, of which, only the first two (?) bear appendages, the succeeding somites being apparently destitute of any organs. These post-cephalic appendages consist of two or three pairs of lamelliform plates (the modified thoracic[1] limbs) united together down the mesial line and attached to the ventral surface of the somites, against which they fit when closed, thus serving as defensive coverings or sheaths to the organs of generation and respiration, which they bear upon their inner and upper surface (see *ante*, Part III, pp. 114—119, figs. 35—38).

The twelve free segments are terminated by a post-anal plate (or "telson") broadly lanceolate or bilobed in *Pterygotus* (Parts I and II) and *Slimonia* (Part III), and ensiform in *Eurypterus* and *Stylonurus* (Part IV).

Viewed as a whole, the EURYPTERIDA present, to my mind, the clearest evidence of a group essentially fitted for easy and tolerably rapid motion, their long and gradually tapering body undoubtedly enclosing within it a correspondingly compact and solid mass of muscles, by which to move it at will through the water, the broad hastate telson (in *Pterygotus* and *Slimonia*) serving both as a powerful propeller and also to depress or elevate its course, whilst its great spatulate swimming-feet would increase its speed or change its lateral direction; lastly, the chelate antennæ seem admirably fitted to seize its prey either when overtaken or approached by stratagem.[2]

All the genera belonging to this remarkable Palæozoic group, the EURYPTERIDA, are now extinct. (See *ante*, Parts I—IV.)

II.—In the second division of the MEROSTOMATA, about to be described, the XIPHOSURA, of which the modern *Limulus* may serve as the type (see Part I, Pl. IX, fig. 1, and Pl. XXXIV—XXXVI), the head is composed of a broad, semilunar shield, the dorsal surface of which rises in the centre, forming a median ridge, upon the fore-part of which,

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[1] *Thoracetron*, Owen, op. cit.

[2] It is highly probable that the chelate antennæ in *Pterygotus* may have also fulfilled the function of claspers in the males, being perhaps longer and stronger than in the female (as we find is commonly the case with the chelate (3rd thoracic) pair in Decapod Crustacea); or they may have been simple palpi in the female, in which case the genera *Slimonia* and *Eurypterus* with simple antennæ would have to be considered as females, and *Pterygotus* with its chelate antennæ as a male, the opposite sex in each case being unknown, or undetermined.

just at the highest central point, the ocelli are placed (Pl. XXXVI, fig. 1, *a* 1), whilst the larger compound eyes (Pl. XXXV, fig. 2, and Pl. XXXVI, fig. 1, I, I,) are situated nearer the sides of the shield, and occupy a point midway upon the two lateral ridges which encircle the central elevated tract or glabella.[1] The front of this great buckler slopes rapidly down to the curved anterior border, the edge of which is strengthened by a bead-like rim. The two genal or lateral portions of the shield are widely produced backward, considerably over-reach the margins of the succeeding thoracic segments, and terminate upon each side in a broad recurved spine

The posterior border of the head-shield is deeply emarginated, and is articulated to the anterior border of the thoracico-abdominal segments by a broad median joint capable of considerable flexure, the post-cephalic segments in the adult modern *Limulus* being soldered together into one nearly homogeneous buckler, and only indicating their original free and movable condition in the young state by the alternation of spines and rounded indentations on each lateral margin, in the hollows of which a series of six spines are articulated on either side in the adult (see Pl. IX, fig. 1, Pl. XXXV, fig. 1 B, Pl. XXXVI, fig. 1 B). In the deep notch formed by the prolongation of the two latero-posterior angles of the hinder border is articulated the powerful triangular "telson" or tail-spine, which often more than equals the length of the rest of the body. The post-cephalic shield is strongly trilobed, and marked by a double row of small oblong indentations corresponding with the entopophysial processes, which are developed from the inner and under surface to support the branchigerous feet.

The length of the head-shield and of the post-cephalic shield is nearly equal, but the former is much broader than the latter.

Beneath the head-shield, which is a double buckler—between the inner and the outer shell of which the soft parts of the animal are completely enclosed (see Pl. XXXIV, figs. 1 and 2, and Pl. XXXVI, fig. 1)—the gnathopods or jaw-feet are ranged. These organs fulfil, as in the Eurypterida, the combined functions of locomotion, prehension, and so much of the sorting and mastication of the food as is needful before deglutition. They are all chelate, the most anterior pair, Pl. IX, figs. 1, 2 (the antennules), is the smallest, and is præ-oral, being attached on either side of a minute epistome, the antennules are not provided with a spinose coxal joint, as is the case with the five succeeding pairs. The second pair is subject to modification in the males of the American species, Pl. IX, fig. 1 *a* (*Limulus polyphemus*), and the second and third in the males of the Moluccan species (*L. moluccanus*). The sixth pair of limbs have stronger maxillary joints, and at the distal extremity (Pl. XXXIV, fig. 4) bear upon the antepenultimate joint a series of lamelliform plates, which, when spread out, greatly assist the animal both in burrowing and walking

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[1] In the Introduction to his 'Monograph on the British Trilobites,' Pal. Soc., Part I, 1864, p. 10, Mr. Salter observes, "The curious so-called *facial suture*, a line of division which is only faintly indicated in *Limulus*, and which has, perhaps, no other representative in the whole Crustacean class, sufficiently distinguishes the Trilobite."

The relative position of the eyes in *Limulus* upon the ridge which circumscribes the glabella or central portion of the shield favours this homology, and although no actual line of suture can be traced dividing the general portion of the head-shield from the glabella in *Limulus*, nor any indication of a disposition to divide along this line, as is commonly the case in Trilobites, we may conclude that they do actually correspond.

Nor is this structure of the head-shield so exceptional as Mr. Salter had supposed. For, whilst Professor Dana and Mr. Spence Bate have shown that the antennal segment constitutes the anterior and upper portion, and the mandibular segment forms the posterior and lower portion of the carapace in the Macrouran and Brachyuran Decapod, the latter ('Annals and Mag. Nat. Hist.,' 1855, 2nd series, vol. xvi, p. 36) has affirmed that the suture which traverses the lower surface of the carapace of the latter forms the line of demarcation between the third and fourth somites, and is homologous with the cervical suture in the Macroura, with that which traverses the dorsal surface of the cephalon in several genera of Trilobites, and, we would add, of *Limulus* also. In this view of the structure of the head in the Crustacea we cordially agree. [See also Spence Bate, 'Brit. Assoc. Reports,' 1875, Bristol, p. 46.]

This, with a small bifid metastome,[1] completes the circumoral appendages.

Behind the mouth are placed six broad, lamelliform appendages, the first of which bears upon its upper and inner surface the ovaries or reproductive organs, and the remaining five the branchiæ (see Pl. XXXV, figs. 1, 6, and 8).

The following details of the internal structure of the living *Limulus* I take from Professor Owen's valuable Monograph "On the Anatomy of the American King Crab, *Limulus polyphemus*" ('Trans. Linnæan Soc.,' 1872, vol. xxviii, pp. 459—506), to whose kindness, and also to the courtesy of the President and Council of the Linnæan Society, I am indebted for permission to reproduce the subjects forming Plates XXXIV, XXXV, and XXXVI of the present Monograph.

On the Anatomy of the American King-Crab, *Limulus polyphemus*, Latr. By Professor Owen, C.B., F.R.S., F.L.S.

§ 1. "*Muscular system.*—The parts sent inward from the crust or exoskeleton are those that afford attachment to muscles, and those which also form or contribute to the joints of the articulate appendages. They are termed 'entapophyses' and 'apodemes.' The 'apodemes' that relate to the cephaletral[2] limbs (Pl. XXXVI, ii—vi) are broader and more complex than those of the thoracetron (ib., vii—xiii). The most conspicuous entapophyses are the following:—A pair of oblong, lamelliform processes descend from the segment confluent with, and forming part of the hind border of the cephaletron[2] at the parts indicated by the ciliate depressions. Six pairs of similar, but rather smaller processes project into the cavity of the thoracetron, from the inner surface of the parts indicated by the oblong depressions. These serve to give attachment to and augment the force of muscles. Analogous entapophyses are developed in most of the articulations of the limbs (Pl. XXXIV, fig. 5 *c*, *e*, *g*) for a like purpose. All these internal processes assume more or less of a cartilaginous character, losing the hardness and colour of the outer crust as they extend inwards.

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[1] Named by Prof. Owen "chilaria," from Χειλάριον, a small lip.

[2] Prof. Owen has proposed in his 'Memoir,' from which we quote so largely, the use of the terms "cephaletron" for the seven anterior somites forming the *cephalic* shield; "thoracetron" for the seven succeeding somites forming the *thorax* or middle body; and he applies Spence Bate's term "pleon" for the hinder *apodal* portion of the posterior shield, or *abdomen*, "including therein the part which Spence Bate calls 'telson,' constituting the characteristic 'tail-spine' of the present singular genus."

"The main movements of *Limulus* in locomotion are those of inflection and extension of the 'cephaletron'[1] upon the thoracetron,[1] and of the tail-spine upon the latter, and reciprocally.

"The fixed points upon which the cephaletral muscles act upon the thoracetron are afforded not only by the apodemata and entapophyses, but also by the representative of an internal skeleton. This (Pl. XXXIV, figs. 1 and 2 *k*) is situated partly in the angles between the gullet and the stomach, thence extending backward a short way along the interval between the beginning of the intestine and the neural axis. It is an oblong, subquadrate plate of sclerous or fibro-cartilaginous tissue, and is chiefly related to the attachment of muscles (Pl. XXXV, fig. 5). It was likened by its discoverer, Straus Dürckheim, to an internal cartilaginous sternum, and may answer to the part which he so terms in the Arachnida. I shall refer to it, without any wider homological signification, as the 'entosternon.'

"*Levatores thoracetri.*—The extensors or, more properly, 'levators' of the thoracetron are a pair of powerful muscles, the fibres of which rise from the low inner ridges indicated or formed by the longitudinal mediilateral grooves or inflections of the carapace.[2] This feature in the accentuation of the upper crust of the 'cephaletron' relates to such favorable condition of origin of the 'levatores thoracetri.' The pair come into contact at the median line, filling the hollow of the roof, of which that line is the mid-ridge; their longitudinal fibres (Pl. XXXIV, fig. 1 *m*, 1) intervene between it and the pericardium as they pass backward to be inserted into the anterior and upper transversely convex process of the 'thoracetron' (*g*), which enters the correspond arch (*f*) of the 'cephaletron.'

"*Depressores thoracetri.*—The flexors or 'depressors' of the 'thoracetron' rise from the dorsal surface of the hinder third of the entosternon (Pl. XXXV, fig. 5 *m*, 2), divide as they pass backward into two groups or a pair, the fibres of which ascend obliquely on each side the intestine, and subdivide into fasciculi, to be inserted into the entapophyses of the thoracetron.

"*Prætrahentes entosterni.*—The power of the 'entosternon' as a fixed point or fulcrum is provided for by other muscles. A strong, longitudinal, subdepressed fasciculus rises from the inner surface of the fore part of the cephaletron on each side, the fibres of which slightly converge as they pass backward to be inserted into the anterior angles of the entosternon (Pl. XXXV, fig. 5 *m*, 3).[1] They tend to draw that part forward, and resist the backward displacement of it, which would otherwise ensue in the action of the 'depressores thoracetri' (*m*, 2). The '*prætrahentes entosterni*' are the main origins or 'fixed points,' functionally, of the great muscles, made 'digastric' by the intervention of the entosternal fibro-cartilage, which depress the thoracetron; when the insertional lamella of the '*depressores thoracetri*' become fixed points, they act through the medium of the entosternon as origins of the digastric muscles deflecting the cephaletron. In like manner, when the insertions of the '*levatores thoracetri*' become the fixed points or origins, those muscles will oppose the '*depressores cephaletri*,' and become '*levatores*' of that part.

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[1] See Note 2, page 186.

[2] The corresponding grooves rendering *Asaphus*, &c., "trilobitic" most probably indicate analogous ridges or entapophyses for the flexor muscles of the segments.

"*Levatores antici sterni*.—But the singular structure which acts functionally as 'endoskeleton' in *Limulus* has additional powers given to it by muscles which, like the mainstay of a mast, steady it in the transverse or lateral directions. From near the fore part of the dorsal surface of the entosternon diverge a pair of sclerous processes, which become tendons of a pair of muscles (Pl. XXXV, fig. 5 *m* 4)[2] about half the size of the '*protractores*' (ib., fig. 5 *m* 3), and which have their fixed points in the antero-lateral part of the cephaletron. The '*levatores*,' by their direction, tend to raise and draw forward the entosternon, and so add their power to the protractors when these muscles are made to act in combination with the '*depressores thoracetri*,' but to the degree in which their oblique course would tend, if one of the pair acted singly, to pull the entosternon sideways, their combined action would add to its fulcral power in relation to the movements of the two chief divisions of the body.

"*Levatores laterales entosterni*.—The steadying of the entosternon is more directly attained by a series of fibres which, rising from ridges due to the inflection of the lateral longitudinal grooves of the cephaletron, descend and converge to be inserted into the posterior half of the lateral borders of the entosternon (ib., *m* 5).

"*Levatores postici entosterni*.—Fasciculi from the dorsal surface (Pl. XXXV, fig. 5, *m* 6), which seem to be the fore part of the series of '*depressores thoracetri*,' ascend, as they retrograde, to be inserted into the lamelliform entapophyses rising from the hind border of the cephaletron, which seem to initiate anteriorly the series of shorter and smaller ones descending from the thoracetron. With the insertion, or rather origin, of the above entosternal muscles, their action would be to retract and raise the entosternon.

"The functions of these '*levatores entosterni*,' in relation to the fixation of the endoskeleton, are more especially in opposition to muscles arising from its lower and lateral parts to be inserted into basal entapophyses of the five posterior pairs of cephaletral limbs. But the principal muscles acting on the basal joints of these members arise from the

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[1] J. vander Hoeven, 'Recherches sur l'Histoire naturelle et l'Anatomie des Limules,' fol. 1838, p. 47, pl. iii, fig. 7 *b*.

[2] Ibid., fig. 7.

'apodemata' or inflections of the ventral crust (Pl. XXXVI, fig. 1, II—VI), forming, or rising from, the articular cavities in the cephaletral plastron for those limb segments.[1]

"The '*levatores telsi*,' if I may be permitted to Latinise Spence Bate's term for the 'tail-spine,' rise from the upper median lateral parts of the inner surface of the thoracetron; the median fasciculi form one elongated muscle (Pl. XXXIV, fig. 1, *m* 7), which is inserted into the upper basal process, and directly tends to raise the spine; there are two shorter lateral masses (*ib.*, *m* 8), converging to be inserted into the same process, but which, if acting independently, would draw the spine outwards as well as upwards. Both median and lateral muscles acting together would raise the spine forcibly, or if the spine were the fixed point, and the thoracetron, depressed at an angle therewith, would tend to raise that part.

"*Depressores telsi.*—Two shorter and broader but powerful muscles (*ib.*, *m* 9), having the double oblique or penniform disposition of fibres, rise from the lower terminal part or segment of the thoracetron (*ib.*), and converge to be inserted into the sides of the basal entapophyses from below the articular condyles of the tail-spine. These, combining in action, depress the tail-spine; their lateral portion, combining with the corresponding one of the *levator telsi*, draws the spine to that side. When the spine was fixed the muscles would act as flexors, extensors, or adductors of the thoracetron.

"Muscular fasciculi for the protraction and retraction of the thoracetral appendages rise from the apodemata of that division of the body.

"*Protractores branchipedum.*—The limb-plates of each lateral moiety of the broad gill-bearing lamella has two principal muscles; one, arising from the outer part of the apodeme in advance, subdivides into fasciculi, which descend, penetrating the fore or under surface of the gill-limb (Pl. XXXIV, fig. 1, IX—XIII), and radiate therein to be attached to the several segments. These fibres protract the limb, change its recumbent for the erect position, and in that movement separate the gill-plates and facilitate the flow of water through their interspaces.

"*Retractores branchipedum.*—These muscles rise from the base of the apodeme of their own gill-foot, near the place of articulation of the latter, and spread upon the hinder, inner, or upper surface of the proximal lamelliform joint before penetrating the interior of the succeeding ones. They retract or draw up the gill-feet, approximate and press together the gill-plates, and squeeze out the water from their interspaces. The insertional fibres of this muscle are shown on the anterior thoracetral lamelliform limb, which serves as a cover or 'operculum' to the genital outlets (Pl. XXXV, fig. 6, *m* 11).

"Some small fasciculi, combining their insertions with the proper muscles of the branchipeds, have attachments to the thoracetral entapophyses, and seem to combine a levator action upon the branchipeds with that of the '*depressores thoracetri.*'

"In the cephaletral limbs (III—VI, Pls. XXXIV and XXXV) the haunch-joint

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[1] J. vander Hoeven, op. cit., pl. iii, fig. 10, *b*, *c*.

(*coxa*, I) is of great transverse extent, and besides affording insertion to the apodemal muscles, which forcibly work the carding-plate, or 'palpus' (Pl. XXXIV, figs. 2—5, *p*), gives origin to muscles acting on the second joint or 'basis' (*ib.*, *ib.*, 2).

"*Extensor basis pedis.*—One of these, of small size, is an extensor of the 'basis' (Pl. XXXIV, fig. 5, *a*), but only in a slight degree.

"The '*flexor basis*' (*ib.*, *b*) is a larger, especially broader, muscle, and bends the 'basis' forcibly upon the 'coxa' or first joint.

"*Flexor merii cnemiique.*—The muscle (*ib.*, *d*) arising from the 'basis' (2) is supplemented by other fibres from the 'merion' or third joint (3), proceeding penniform-wise to an entapophysis (*c*), attached to the base of the 'cnemion' or fourth joint (4). The action of this series of fibres is to bend both merion and cnemion. An 'extensor of the cnemion' is feebly developed.

"*Flexor propedis.*—The cavity of the cnemion is chiefly occupied by the penniform flexor (*f*) of the 'propes' (5), upon which it acts chiefly through the medium of the 'apodeme' (*e*), attached to the base of that joint.

"*Flexor dactyli.*—In like manner the penniform muscle, in the swollen basis of the 'propes,' draws, through the medium of the entapophysis (*g*), the 'dactylus' (6), powerfully, in contact with the claw-like process of the 'propes' (5).

"In the 'propes,' or fifth joint of the maxilliped, fasciculi of the muscular fibres are grouped to be inserted into the short basal apophyses of the lamelliform appendages (Pl. XXXIV, fig. 4, 6), which they tend to approximate, or to close upon or around the terminal chela (*ib.*, 7). These plates, which radiate from the end of the 'propes' like the petals of a flower, are expanded by being pressed against the mud or sand, and seem to require muscles only for closing them, so as to facilitate the withdrawal of the limb.

"The application of the maxillipeds in locomotion was observed by W. A. Lloyd, Esq., the constructor of the aquarium at Hamburgh, of which he was for some years the conservator, and subsequently the constructor of that at the Crystal Palace, of which aquarium he is now the manager.

"At Hamburgh, specimens of *Limuli* were kept alive from the year 1865 to 1870. From his observations of these Mr. Lloyd informs me, 'the ulterior pair of limbs' (maxillipeds, VII) 'are not employed for walking, but exclusively for burrowing. These limbs are terminated by four long, stiff, oval, or leaf-shaped lobes, jointed at their base to the leg, and capable of being opened and closed in a four-radiate manner. When it wishes to burrow these two limbs are sometimes alternately and sometimes simultaneously thrust backwards below the carapace quite beyond the hinder edge of the shell, and in the act of thrusting the lobes or plates on each leg encounter the sand, the resistance or pressure of which causes them to open and fill with sand, a load of which at every thrusting operation is pushed away from under the crab, and deposited outside the carapace. The four plates then close, and are withdrawn closed, previously to being opened and charged with another load of sand, and at the deposit of every load the whole animal sinks deeper in its bed, till it is hidden all except the eyes. The great over-arching shield of the carapace again prevents one from seeing whether this excavating work is being aided by the fanning motion of the branchial false feet, but I *think* such a fanning is going on, as I have seen signs of sand being driven out as if urged by a current of water.

"Mr. Lloyd thus describes the use of the tail-spine in locomotion:—'The animal having climbed up a rock in the aquarium till it has got near the top of the tank (which in Hamburgh contained a depth of thirty inches of water), and having assumed a vertical position, it leaves go its hold on the rock and allows itself to fall back into the water; but its downward fall is instantly checked, and the creature propelled upwards by the powerful flapping of its false branchial feet, and when the impetus given by these appendages ceases the animal again sinks down, but is prevented from falling prone on the floor of the tank by alighting on the tip of its tail-spine. The moment this happens, and before the creature has lost its balance on the spine, the false feet make another flap and give another impulse upwards and forwards; all this time the position of the carapace is slanting, the top inclining downwards at an angle of about 45°, the hinder shell being at another angle, and the tail-spine hanging down vertically, and so it progresses by a combination of flapping and hopping till it reaches the limits of its tank and sinks to the ground. The *Limulus* was fond of thus going about at night, generally remaining on the sand all day.

"'Another use made of the tail-spine was as a lever by means of which it righted itself when it fell off a rock on its back. The spine is then bent, its point is planted in the sand so that it makes an acute angle with the carapace, which is then so far raised that some of the feet are enabled to grasp a projecting surface, and the crab then turns over.'

"The maxillipeds, no doubt, aid in burrowing, but the chief fossorial agent, as indicated by the size and disposition of the principal muscular masses, is the great 'cephaletral' digging shield.

"In an interesting paper by the Rev. S. Lockwood, he thus describes the American species:

"'The King-Crab delights in moderately deep water, say from two to six fathoms. Except in the case of the very young, which are probably carried hither and thither by the tidal flow, it never seeks the shallow water save for the purpose of reproduction.

"'It is emphatically a burrowing animal, living literally in the mud, into which it scoops or gouges its way with great facility by means of the anterior edge of its enormous cephalic shield. In the burrowing operation the forward edge of the anterior shield is pressed downwards and shoved forwards, the two shields being inflected, and the sharp point of the tail presenting the fulcrum as it pierces the mud, while underneath the feet are incessantly active scratching up and pushing out the earth on both sides. There is a singular economy of force in this excavating action, for the alternate doubling up or inflecting, and straightening out of the two carapaces with the pushing-purchase exerted by the tail-spine, accomplish both digging and subterranean progression. Hence the King-Crab is worthy to be called the 'Marine Mole.'[1]

§ 2. "*Nervous System.*—The chief part of the neural axis is in the form of an elliptic ring girting the œsophagus. Of this ring three views are given, one from above (Pl. XXXVI, fig. 1, *a* B), one from below (Pl. XXXV, fig. 1, *a* β), and one from the side (Pl. XXXIV, fig. 1, *a* β); in order to show, besides the shape of the part itself, the precise position of the nerves arising therefrom or connected therewith. For the origin of a nerve is an important element in determining the homology of the part it supplies; and such determinations have weight, as will be seen, in wider questions, extending, in the case of *Limulus*, *e.g.*, even to class affinity.

"The part of the neural axis anterior to the œsophagus (Pls. XXXIV, XXXV, and XXXVI, *a*), and which, were the tube straightened and the mouth brought to its ordinary position at the forepart of the body, would be superior or dorsal in position, is an oblong mass, concave where applied to the tube (Pl. XXXVI), convex on the opposite side (Pl. XXXV), 3 lines in length and 4 lines in posterior or basal breadth, where its angles are continued into the side parts of the ring (Pl. XXXIV, fig. 1, β). There is no trace of lateral bipartition of the superœsophageal or cerebral part of the neural axis. The substance of the ring shows the same axial or longitudinal extent behind as before the œsophagus; viewed from below, as in Pl. XXXV, fig. 1, it seems to extend rather further before contracting to form the ganglionic chord. The narrowest parts of the ring are at the sides of the œsophagus; but this is transversely; vertically the substance there is equal to that of the hind part of the ring (Pl. XXXIV, fig 1, β). Two commissural bands unite the lateral parts of the ring Pl. XXXVI). The ganglions (Pls. XXXIV, and XXXV, δ, ε, ζ, η, θ) are confined to the thoracetral region.

"*Ocellar Nerve, n a.*—The first pair of nerves is the 'ocellar' (Pls. XXXIV, XXXV, and XXXVI, *n a*). They rise, with an interval of their own diameter, from the fore and upper part of the brain (Pl. XXXVI *a*), diverge with a gentle curve as they advance, bend round the front convexity of the stomach (Pl. XXXIV, fig. 1, *n a*), and ascend, converging to terminate each in its ocellus (*ib.*, *a*, 1). The length of the nerve is two inches.

"*Ocular Nerve, n* A.—The second pair of nerves is the 'ocular' (*ib.*, *n* A). Each nerve rises from a small conical process of the brain (Pl. XXXVI), where the special quality of an optic ganglion may be surmised to dwell. An interval of the basal breadth of the swelling divides the ocular from the ocellar nerve. The ocular nerve curves upwards, crosses the gizzard near the pylorus (Pl. XXXIV), then more abruptly bends outward (Pl. XXXVI), coasting round the apodeme (II) of the second limb, and retrograding obliquely to the compound eye, near which the nerve divides into a larger dorsal and smaller ventral chord. The dorsal division (Pl. XXXV, fig. 2, *d*) soon expands, and resolves itself into a fasciculus of nervules, which subdivide, and finally supply or form the retinæ of the lenses at the upper and hinder part of the compound eye. The ventral, which is also the anterior division (*ib.*, *v*), is continued before expanding and resolving into the plexus which supplies the retinæ to the lenses at the lower and forepart of the compound eye.

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[1] 'The "Horse-Foot Crab," '*Limulus polyphemus*,' by the Rev. S. Lockwood, Ph. D., the American Naturalist, vol. iv, 1870, p. 257.

"*Gastric Nerves.*—Two pairs of nerves arise posterior to the ocular pair. The nerves of the first pair (*n*, 3, Pl. XXXVI) pass forward, give filaments to the œsophagus and stomach, and are continued on into the hepatic and ovarian substance at the forepart of the carapace.

"*First Epimeral Nerve.*—The nerves of the second pair (on the outer side of the symbol *n*, 4, Pl. XXXVI) diverge, extend along the forepart of the anterior low and simple apodeme (II), subdivide, and are lost in the tissues of that part of the segment; answering, in position, to the epimerals[1] of the type segment. The term 'epimeral' will, accordingly, be given to this and the succeeding serially homologous nerves.

"*Second Epimeral Nerve.*—A somewhat larger nerve rises immediately behind the foregoing; the pair (Pl. XXXVI, *n*, 5) slightly diverge and ascend, when each second epimeral nerve bifurcates. One branch coasts along the anterior apodeme, the other inclines towards the interspace between that and the second more prominent apodeme, supplies muscular fibres thence arising, and gives off a recurrent filament (*n*, 6), traceable along the outer ends of the succeeding apodemes (II—VI, Pl. XXXVI), at a little distance from them, as far as the seventh epimeral nerve, where this begins to ramify.

"*Antennular Nerve.*—This nerve (*n* II, Pls. XXXIV and XXXV) rises from the under part of the base of the brain (*a*, fig. 1, Pl. XXXV), is rather larger than the second epimeral nerve, and supplies the first small forcipated pair of limbs, the homologue of the first, or inner pair of antennæ in higher and more differentiated Crustaceans.

"Two filamentary nerves rise from the interval between the antennular and antennal nerves at the beginning of the lateral parts of the ring (shown in Pl. XXXV).

"*Antennal Nerve.*—This nerve (*n*, III) is more than twice the size of the antennular one; it supplies the second limb (Pl. XXXV, III), which is sexually modified in the male of *Limulus polyphemus.* This limb, forcipated like the rest in the female, is the homologue of the outer and larger pair of antennæ in higher Crustaceans; and its origin is præ- or supra-œsophageal in *Limulus.*

"*Third Epimeral Nerve.*—From the dorsal aspect of the lateral part of the neural ring rises the third 'epimeral nerve' (*n*, 7, Pl. XXXVI). It runs forward and outward above the interspace between the second (*ib.*, II) and third (III) apodemes, and is resolved into a plexus of filaments beyond that interspace, which are lost in the glandular and other tissues of that region.

"*Mandibular Nerve.*—The third limb nerve (Pl. XXXV, *n*, IV), of the same size as the second, comes off behind it, from the lateral part of the ring, β, and supplies the limb homologous with the 'mandible' (so called) in higher Crustaceans; which limb is marked IV in Pls. XXXIV and XXXV, where the nerve is traced through the coxal and basal joints.

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[1] Owen's 'Lectures on Invertebrata,' p. 298.

"*Fourth Epimeral Nerve.*—From the dorsal aspect of the corresponding part of the neural ring is sent off the 'fourth epimeral nerve' (*n*, 8, Pl. XXXVI), having the same course and apodemal relations as the second and third of this series.

"*Premaxillary Nerve.*—This, with a more posterior origin than the mandibular nerve, repeats the characters of that nerve, in relation to the fourth limb, or homologue of the 'præmaxilla,' or first or anterior maxilla, in higher Crustaceans. The nerve (*n*, v) is shown in Pls. XXXIV and XXXV, entering and traversing the 'coxa' and 'basis' of the limb marked v. This limb is sexually modified in the male of *Limulus Molluccanus*, but not in the species here dissected.

"*Fifth Epimeral Nerve* (*n*, 9, Pl. XXXVI).—This repeats the relative position of origin to the premaxillary nerve which the antecedent one (*n*, 8) bears to the mandibular nerve, and holds the same relation in its course to the apodemes IV and V. It forms the plexus beneath that of the optic nerve, beyond which the filaments are lost in the tissues there. The optic nerve crosses dorsad of the first four epimeral nerves in its course to the compound eye.

"*Post-maxillary Nerve.*—The fifth limb-nerve (*n*, VI, Pls. XXXIV and XXXV), with a more posterior origin and a course more obliquely backward, repeats in limb VI the homologue of the post-maxilla or second maxilla, in higher Crustaceans the characters of the 'premaxillary nerve' in relation to limb v.

"*Sixth Epimeral Nerve* (*n*, 10, Pl. XXXVI).—This repeats the same relative position of origin to its answering limb-nerve as does *n*, 9; it is continued further obliquely backward before bending outward to its interapodemal space, and bifurcates before entering there, the hinder division descending to supply the strong adductor muscle of the sixth limb (VII in Pls. XXXIV and XXXV).

"*Maxillipedal Nerve* (*n*, VII, Pls. XXXIV and XXXV).—The nerve supplying that limb has its origin between the post-maxillary nerve and the beginning of the abdominal ganglionic chord, γ. It repeats the character of the antecedent limb-nerves in relation to its own articulated appendage, which is the homologue of the 'maxilliped' in higher Crustaceans.

"*Palpal Nerves.*—At the interspace between the origins of the post-maxillary and maxillipedal nerves, as in that between the latter and the ganglionic continuation of the neural centre, arise filaments which supply the spinigerous process or 'palp' of the compressed denticulate haunch-joint (Pl. XXXIV, figs. 2 and 5, *p*).

"*Chilarian Nerve* (Pl. XXXIV, fig. 1, *n**, and Pl. XXXV, fig. 1, *n**).—This rises between the origins of *n*, VII and *n*, VIII; it is appropriated to and richly ramified in the leaflike spinigerous appendage, articulated behind the base of the maxilliped, and closing posteriorly the circumoral armature. The serial homology of the chilarian with the palpal nervules lends some countenance to that of the appendage, so supplied, being a detached spinigerous process or 'palpus' of VII."

[Referring elsewhere (at p. 464) to this pair of compressed spinigerous oblong plates, situated immediately behind the sixth pair of circumoral apppendages, and closing as it were the buccal orifice behind, Professor Owen observes "they recall to mind the pectinate appendages of the thoracetron in *Scorpio*. In *Limulus* they close or complete the oral armature posteriorly, forming the 'lèvre inférieure' of Cuvier, and a corresponding member of the 'trophi,' according to Savigny; but Latreille preferred to regard them as the haunches or jaw-lobes of the sixth pair of limbs detached. The haunch-joints, however, are present, though less dentated in the sixth pair of appendages (Pl. XXXIV, fig. 4, 1 *p*). The appendages in question have their own distinct pair of nerves (Pls. XXXIV and XXXV, fig. 1 *n**) arising between the origins of the main nerve of the limb (VII) and that of the ganglionic chord, suggestive of a serial homology with the palpal nervules. I am not," he adds, "however, satisfied with this as a ground for regarding the parts in question as detached limb-palps; and I therefore propose to call them '*chilaria*'" (from *χειλάριον*, a small lip).

Vander Hoeven refers to them as "the two pieces placed behind the sixth pair of feet, and which some authors consider as forming the lower lip."[1]

Huxley considers it "the rudimentary metastome," and, referring to the variation which the plate undergoes, mentions that "in *Calanus* it is excavated anteriorly by so deep and wide an emargination, that it almost appears to consist of two distinct lobes. In *Pontella*, on the contrary, the metastoma is a large flattened plate, whose terminal emargination, though wide, is not deep.[2]

I have invariably adhered to this view of the 'chilaria' in *Limulus*. Indeed, there seems no reason to doubt that this pair of oval oblong plates, the bases of which are united on the median line of the body, represents the inferior lip, and is homologous with the great conjoined but bilobed metastomatal plate placed precisely in the same position behind the mouth in *Eurypterus* and *Pterygotus*,[3] and I find that the researches of my distinguished friends, Dr. Anton Dohrn[4] and Dr. A. S. Packard, jun.,[5] into the development of *Limulus polyphemus*, have led them to adopt the same conclusions (see 'Development of *Limulus polyphemus*,' *infra*).—H. W.].

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[1] J. vander Hoeven, 'Recherches sur l'Histoire Naturelle et l'Anatomie des Limules,' Leyden, 4to, 1838, p. 48, 7 plates.

[2] 'Medical Times and Gazette,' 1857, vol. xv, p. 188; 'Mem. Geol. Surv.,' Mon. I, 1859, "On the Anatomy and Affinities of the Genus *Pterygotus*," pp. 33 and 34.

[3] See 'British Assoc. Reports' for August, 1871, on "The Structure of Fossil Crustacea;" also 'Geol. Mag.,' 1871, vol. viii, p. 524. See also Parts I—IV of this Monograph.

[4] "Zur Embryologie und Morphologie des *Limulus Polyphemus*" ('Jenaischen Zeitschrift,' Bd. VI, Heft 4, 1871, p. 639.

[5] "On the Development of *Limulus Polyphemus*," 'Mem. Boston Soc. of Nat. Hist.,' 1870, vol. ii, p. 156.

"*Seventh Epimeral Nerve* (*n*, 11, Pl. XXXVI).—This arises dorsad of the origin of the maxillipedal nerve, passes backward and outward to its proper apodeme (vi), where it divides, and, running onward, ramifies to supply the tissues in the hinder produced angles of the cephaletron.

"*Eighth Epimeral Nerve* (*n*, 12, Pl. XXXVI).—This is one of the same system of dorsal nerves, succeeding the seventh; it passes backward and slightly outward along the dorsal margin of the seventh apodeme (vii), and dips into the articular depressions between the cephaletron and thoracetron.

"*Opercular Nerve*.—The hindmost pair of cephaletral ventral nerves (*n*, Pl. XXXIV, and *n*, viii, Pl. XXXV, fig. 1) is given off at or just before[1] the continuation of the neural ring into the 'ganglionic chord.' The nerves of this pair run along the sides of the latter for about 8 lines, then slightly diverge, curve outward, and send off one or two filaments laterally, before descending to penetrate the base of the anterior or opercular leaf-foot, or coalescent pair of limb-appendages of the segment anchylosed to the back of the cephaletron.

"The corresponding dorsal pair of nerves (*n* 13, Pl. XXXVI) also course along the sides of the ganglionic chord before diverging to ramify in the middle third of the interspace between the cephaletron and thoracetron.

"The ganglionic chord (γ, Pls. XXXIV and XXXV), extends backward about an inch before its first ganglion (δ) is formed; this is followed by three others (ε, ζ, η), and a terminal swelling (θ) situated about an inch and a half from the joint of the tail-spine. The interganglionic tracts average in length about 2½ lines, slightly shortening as the chord recedes.

"Each of the four anterior ganglions gives off two pair of principal nerves, one dorsal and anterior (*n*, 14—17, Pl. XXXVI) the other ventral or posterior (*n*, ix—xii, Pls. XXXIV and XXXV), these terms not being absolute, but meaning the approximate relative position of the places of union of the nerves with the ganglion. The dorsal nerve is a serial repetition of the antecedent epimeral ones. It passes outward along the contiguous apodemal interspace, on emerging from which it divides; the posterior branch quickly subdivides; the anterior branch continues further before subdividing; all these filaments incline obliquely backwards before distributing themselves among the tissues of their corresponding abdominal segments. The dorsal nerves (*n*, 17, Pl. XXXVI) from the fourth ganglion run backward a short way before inclining outward. A filament of each of the thoracetral epimeral nerves can be traced to the movable side-spine of its segment.

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[1] "This lends countenance to the idea that the 'opercular limb,' viii, is the last of the cephaletral series." [See remarks on this plate in *Pterygotus, ante*, Part I, p. 40, *et seq.*—H. W.]

"The ventral nerve goes obliquely outward and backward to the space or joint between its own segment and the one in advance, penetrates the branchial leaf-limb at the part or moiety of its own side, distributes many filaments to the basal joint, and is continued on through the second and third joints, before being finally resolved in the fourth and terminal joint (Pl. XXXIV *n* IX—XII). More minute filaments are sent off; usually between the origins of the two chief nerves, from the four ganglions.

"The terminal ganglion (*θ*, Pls. XXXIV and XXXV) represents the coalescence of the nerve-centres of at least three segments. Its anterior dorsal pair of nerves (*n* 18, Pl. XXXVI) traverse the interval between the fifth (XII) and sixth (XIII) thoracetral apodemes, in a course more obliquely backward than the antecedent pairs. The corresponding anterior ventral nerve (*n* XIII, Pls. XXXIV and XXXV) supply the sixth pair of leaf-limbs or fifth branchial pair (XIII). Below the origin of this pair, nervous filaments (*r*, Pl. XXXIV) pass off to the lower fourth of the intestine.

"The second ventral pair (*n* XIV, ib.) is chiefly distributed to the fibres of the flexor muscles of the tail-spine, arising from and occupying the soft, rather tumid tract, which resembles a leaf-foot soldered down to form the covering of the hindmost part of the ventral surface of the thoracetron.

"The third pair of principal nerves from the terminal ganglion represents a bifid continuation of the neural axis (Pl. XXXV, *l*). After a course of about three lines each sends off a nerve (*n* XV, ib.) belonging to the ventral series, which supplies the hindmost or postanal region of the abdomen, affording the articular surface for the tail-spine.

"After sending off the above nerve, each continuation of the chord forms an oblong loop (ib., *k*), which, prior to the removal of the vascular sheath, looks like a ganglionic swelling;[1] beyond which the chord (λ, Pls. XXXIV and XXXV) continues along the side of the tail-joint, and, on entering the cavity of the tail-spine (c), resolves itself into a fasciculus of fine nerves (ib., *pl.*), resembling the 'cauda equina' of anthropotomy. But in this bundle a principal filament, or continuations of the chord (Pl. XXXIV, *μ*), can be traced about a third of the way down the spine. These nerves seem to constitute the major part of the tissues in the hollow of the spine, and render a marvellous supply of neurine to so hard, inflexible, and seemingly insensible a part.

"Each chord, λ, from the ganglionic loop sends off nine nerves, four directed towards the ventral (Pl. XXXV, fig. 1, *pl.*), four towards the dorsal (Pl. XXXIV, fig. 1, *a* 1—4) region of the spine: the ninth nerve, being of larger size, claims to be the continuation of the bifid neural axis. If the dorsal and ventral divisions be regarded as those of four nerves serially homologous with such divisions of antecedent primary pairs, they would indicate as many segments coalesced in the fore part of the spine. The ninth nerve and its divisions supply in a similar way the rest of the tail-spine.

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[1] As represented by Vander Hoeven, op. cit., pl. iii, fig. 2 *c*.

"Seeing the relations of these nerves as continuations of the neural axis, and the like relation of the artery of the spine to the dorsal vessel, I long ago (writes Prof. Owen) concluded the spine itself to be a continuation of the series of body segments, to be serially homologous therewith, and not with their 'appendages.' The coccygeal style of the Frog's endo-skeleton[1] is analogous to the tail-spine of the King-crab's exoskeleton. The antecedent part (*abdomen*, H. W.) wherewith the spine is articulated has no limbs. Is it also part of the '*pleon*'? (*abdomen*, H. W.), and does the post-ganglionic part of the neural axis indicate the extent of such part?"

[In an interesting conversation with the celebrated carcinologist Professor Henry Milne-Edwards in October, 1873, shortly after the publication of Professor Owen's Memoir from which I have so largely quoted, we discussed the question of the homologies of the tail-spine or 'telson' in *Limulus*, and he then frankly expressed his opinion that the nerve-structure described by Professor Owen as characterising the tail-spine of *Limulus* warranted the conclusion of that distinguished anatomist, and that it no doubt confirms his view that it represents the posterior segments of the rudimentary abdomen.

Although this conclusion differs from that expressed by many other writers, as well as by myself, who had considered the 'telson' or tail-spine as a median appendage and not a true segment (in which view its development at a later period in the life of the young King-crab seemed to lend confirmation), nevertheless I felt bound to reconsider the facts most carefully, and also to ascertain, if possible, whether there was any evidence which might be adduced from fossil forms bearing upon this question *pro* or *con*.

The evidence afforded by *Hemiaspis limuloides* (see Part IV of this Monograph, pp. 174—177, woodcut, fig. 64, and Pl. XXX, figs. 1 and 2) in favour of Prof. Owen's view of the telson in *Limulus* had not escaped the attention of that eminent observer.

At p. 176 I wrote as follows: In *Hemiaspis* "the abdomen consists of only three segments, each 2 lines in breadth and 1½ line in depth. The first has no epimera, and appears to move freely at its articulation with the sixth thoracic segment. The second and third segments have small epimeral pieces, which are bilobed, with the posterior lobe more pointed. A line of small tubercles runs down the centre of these three joints, which are somewhat raised at their articular borders.

"The smallness of the abdomen, and its reduction from the assumed normal number of six segments to three, seems to indicate a form by which, with the help of others, we may bridge over the interval that has hitherto existed between these two groups, the *Eurypterida* and the *Xiphosura*" (see woodcut, fig. 72, p. 200).

In his Monograph on the anatomy of the American King-crab Prof. Owen writes (p. 500):

"Segments indicated by the nerve-pairs, but concealed or suppressed by the crust at the base of the tail-spine in *Limulus*, were realised in *Hemiaspis limuloïdes*, H. Woodw.

"The progress from the general to the special, from vegetative repetition to concentrative unity, is exemplified in the living representative of the old form discovered by Salter in the bed of a Silurian sea now contributing to form the county of Shropshire (see woodcut of *Hemiaspis*, reproduced, fig. 72, p. 200).

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[1] Owen, 'Anatomy of Vertebrates,' vol. i, p. 49, fig. 44 *c*.

"The ancestral 'pleon' (*abdomen*) has been almost 'rubbed out' in the thousand-fold generations of which the Salem King-crab is the heir; but the palæozoic taint sticks to the nerve-element. Or shall we say that *Limulus*, made perfect for its sphere and habits of life, must have its 'alpen-stock' unbroken, of compact stuff without joints near the grasped end? But then the teleologist has to give an account of the intermediate or 'evolutionary transitional' condition of the three 'pleonal' (*abdominal*) segments manifest outwardly, as doubtless by their nerve-pairs and probably ganglion-centres within, but soldered together or 'anchylosed' in König's and Baily's *Bellinurus*." (Owen, op. cit., p. 501.)

By the kindness of Mr. Robert Etheridge, Jr., F.G.S., Acting Palæontologist on the Geological Survey of Scotland, I have received from him for examination a 'telson' or tail-spine of *Stylonurus*, discovered by James Powrie, Esq., F.G.S., of Reswallie, Forfarshire; in the grey micaceous, "Lower Old Red Sandstone" of the Sidlaw Hills, Forfarshire, which have already yielded to that ardent geologist such a grand series of Fish and Crustacean remains (see Parts I and IV of this Monograph, &c.).

Mr. Etheridge at once detected the importance of this specimen, and obtained permission of Prof. Geikie, F.R.S., the Director of the Geological Survey of Scotland, that it should be placed in my hands for examination and description. It is figured in the accompanying woodcut (Fig. 73, p. 200).

The specimen measures nearly seven inches in length, and is slightly injured at each extremity, which renders its original full length rather indeterminate, although from the curvature of the lateral borders it would seem to be nearly entire. Its greatest breadth is an inch and a half. The flat, central part is one inch in breadth. The borders are raised on each side, the centre being flat; but as we are looking at an intaglio impression of the fossil, the original, no doubt, had the centre raised and the borders bent downwards. In form it differs from *Stylonurus Scoticus*, being more elongated and straighter, and less spatulate in outline, agreeing better with *S. ensiformis*, H. W., from the same locality, and also collected by Mr. Powrie (see Part IV of this Monograph, Pl. XXI, fig. 5).

What renders this specimen of so much interest is the fact that it affords clear evidence of segmentation, the central part being divided by ten transverse lines, which extend from side to side, but do not cross the raised lateral border (save in the case of the sixth and seventh from the proximal end, which slightly indent it). The border of the telson is finely serrated on either side, but no scale-markings are visible.

This specimen appears to lend important weight to Professor Owen's conclusion as to the compound nature of the "telson" in *Limulus polyphemus*, and I have therefore felt that its introduction here would prove both opportune and appropriate.

The evidence of concealed segments afforded by the dichotomising nerve-fibres of the abdomen and 'telson' in recent *Limulus* under dissection (see Pls. [illegible]

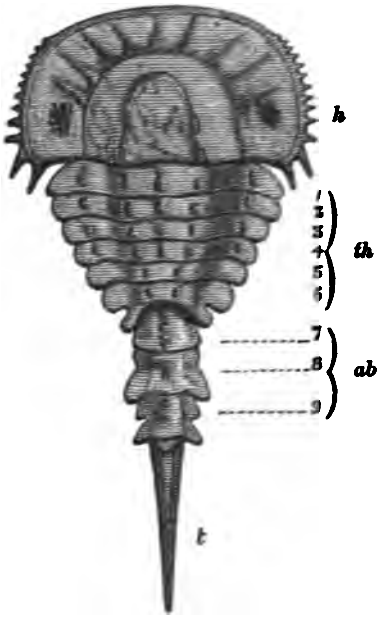

FIG. 72.—*Hemiaspis limuloides*, H. Woodward, Lower Ludlow, Leintwardine.

h, the head; *th*, the sixth thoracic segments; *ab*, the three abdominal somites; *t*, the telson.

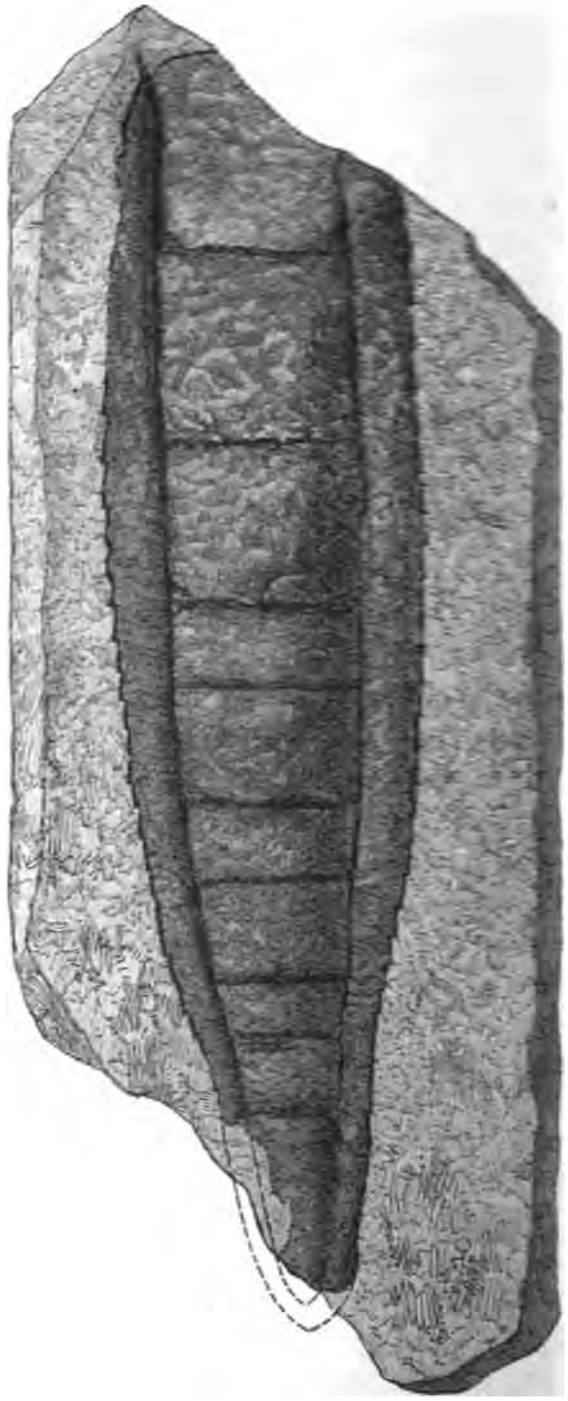

FIG. 73.—Tail-spine of *Stylonurus*, sp. (natural size), Lower Old Red Sandstone, Forfarshire. Drawn from a specimen in the Museum of the Geological Survey of Scotland.

and XXXVI) is here confirmed by traces of external persistent segmentation in the 'telson' of an ancestral type, dating back to the "Lower Old Red" period.—H.W.]

§ 3. *Digestive System.*—"This system of organs includes a 'mouth,' with instruments for seizing and comminuting the food, a 'gullet,' a 'stomach,' an 'intestine,' with vent and accessory glands, of which, in the present genus, the 'liver' only has been recognised.

"The mouth is median, and situated, as in other masticating Crustacea, on the under surface of the body; it is, as in them, surrounded by modified portions of articulate limbs, working laterally, but resembles that in Spiders in respect of its distance behind the fore border of the cephaletron (Pl. XXXIV, fig. 2). The circumoral integument is yielding and elastic, cushioned out with soft tissues, including fibres, interlacing, and susceptible, if muscular, of giving change of form and position to the thick and prominent lips, endowing them with movements, small in extent, but various, for seizing the morsels of food torn by the haunch-palps or 'carders' (ib., *p*, *p*). The thick labial epithelium yields to such movements by transverse folds or indents. The mouth opens on a plane not only behind that of a basal attachment of the antennules (or 'first pair of chelate appendages,' ii), but also clearly behind that of the basal attachments of the 'second pair' or antennæ (iii). Nor can those of the 'third' pair be said to be placed 'posterior to the mouth.' Their nerves arise rather in advance than behind the œsophageal tube; and their haunches are on the transverse parallel of the anterior lip, as shown in Pl. XXXIV, fig. 1, *n* IV, and fig. 2, *p* IV. In a general way the mouth of *Limulus* may be said to occupy the interspaces of the haunches (*coxæ*) of the right and left limbs, iii—vii, these limbs being crowded or close-packed at their basal articulations on each side of the mouth, whence they diverge to their pincer-shaped tips. The haunches are compressed as if squeezed together, and their under or median borders are produced with a convex margin, which, with more or less of the contiguous, flattened surface, is beset with sharp, short, slightly curved spines. These are not mere processes of the chitine, but are slightly moveable, their base being articulated to a pit. The spiny plate, or 'palp,' of the first of these jaw-feet (iii) is inclined backward, and overlaps part of that of the second (iv), which has a like relation to the third (v); this is set more transversely, and is wedged, as it were, between the second and fourth. The haunch of this foot (vi) has a similar position between that of the third (v) and the somewhat less spiny haunch of the last pair of legs or 'maxillipeds' (vii). This complete series or circle of carding instruments is bounded in front by the three-jointed antennæ (ii), having the same chelate structure as in the multiarticulate ones of *Pterygotus;* it is closed behind by the 'chilaria' or pair of appendages" marked * in Pls. XXXIV and XXXV.

"The operation of these circumoral instruments in the living King-crab is thus described by the Rev. Samuel Lockwood, Ph.D., a close and accurate observer of its habits (see the 'American Naturalist,' vol. iv, p. 260):

" 'The food is held immediately under the mouth by the claws or nippers of the anterior pair of jawless feet (antennules), aided if necessary, by some of the others. The basal joints or manducatory haunches then begin an alternating motion of these members upon food by drawing one of the spiny or rasp-like joints against the opposite one of the same pair, the food, of course, being between the two. This chewing by means of these opposing rasps reminded me of the hand-carding process, in which the card held by the right hand is brought towards and against the one held in the left hand, the wool being between; then the right hand card is held still, and the left hand duplicates the motion, and so on. The fine particles rasped off by the incurved teeth pass into the mouth.'

"The tumid and wrinkled margins of the mouth quickly contract to an œsophagus about a line in diameter. This tube (Pl. XXXIV, fig. 2 *œ*) curves upward and forward in a course of 1½ inch, then dilates into a conical proventricular cavity (*r*) extending downward, about 5 lines in depth by 3½ in breadth at the base. From the fore part of the base a second short canal ascends, to terminate by a slight vascular prominence in the stomach (*s*). The epithelium, or modified chitine, continued from the mouth along the gullet and proventricular, becomes suddenly thickened in the stomach, and is disposed in numerous transverse ridges. The muscular coat of the stomach is concomitantly strengthened, attaining at one part a thickness of 3 lines. The pyloric end (*mt*) projects as a truncated cone, 4 or 5 lines long, into the dilated beginning of the intestine (*i*). The truncated apex of the pyloric cone is slightly tumid. The epithelium lining that part has resumed its thinness and subtransparency.

"The intestinal tunics appear to be reflected from the base of the pyloric cone; they define a dilated beginning of the canal, and gain a slight thickness of the muscular coat as they contract to the common size of the intestinal tube, the area of which is about 5 lines in transverse and 3 lines in vertical diameter. The tube goes nearly straight to the vent (Pl. XXXIV, fig. 1 *i*, *v*), but, about half way there, it contracts transversely, and exchanges its oval for a circular section, with a diameter of 2½ lines. Near the vent it again expands, chiefly transversely, and the muscular coat there gains somewhat in thickness. The vent (Pl. XXXIV, fig. 1 *v*) is a transverse slit with tumid margins, just anterior to the joint between the thoracetron and pleon.

"The contents of the alimentary canal were pulpy and scanty. The principal food of the *Limulus polyphemus* is stated by Dr. Lockwood (*loc. cit.*) to be Nereids, routed by the cephaletral limbs out of the mud or sand displaced in the act of burrowing.

"The only gland in communication with this canal is the liver. It is of great size; its minute terminal acini are compactly massed together, and occupy most of the space in the cephaletron not given to other organs, mainly the generative, the ramifications of which interlace with the hepatic lobes. This mass extends forward to the space anterior to the stomach, and backward by a narrow tract on each side of the intestine in the 'thoracetron.' The lobes, or larger groups of acini, form a close-packed series on each side, corresponding in the main in number with the apodemal spaces and the epimeral nerves. The least unsuccessful trials of injecting the terminal canals and acini indicated the greater transverse and less longitudinal extent of the hepatic lobes or primary divisions of the gland. The gathering tubes of the initial or acinal ducts of these lobes course, in the main, transversely towards the intestine until they quit the lobe, when they converge abruptly to form the terminal duct. The anterior of these receives the tributary ducts of the four chief anterior divisions of the liver; the posterior terminal duct is formed by the union of the same number. The ducts of two or three of the anterior lobes unite to form that which enters the main or terminal anterior duct; those from the four posterior lobes, unite and enter the posterior terminal duct by two canals. The arrangement, however, may be varied in other specimens. But the principle of segmental constitution as here exemplified will be found, I doubt not, in all *Limuli*. It indicates the liver to have been developed in relation to the primitive composition of the cephaletron, of seven or more antero-posteriorly succeeding segments, and that there was a pair of livers or hepatic lobes to each. It interestingly exemplifies the way of subsequent concentrative growth characteristic of the mature and procreative individual.

"The bile is conducted to the intestines by two terminal ducts on each side; the first pair (fig. 2, Pl. XXXIV *l*) open upon the sides of the beginning of the tube, where it contracts to the ordinary calibre; the second pair (ib., *m*) open about 9 lines beyond, and nearer the dorsal part of the intestine.

"As in the King-crabs, certain Spiders (*Epeïra*, e. g.) have their ventral mouth provided anteriorly with a chitinous plate, 'labrum' or 'prostome,' and posteriorly with a 'labium' or 'metastome' which is soldered to the cephaletral plastron, not bifid and movable as in *Limulus* (Pls. XXXIV, and XXXV, fig. 1, *). The œsophagus rises, at first, vertically dorsad, then bends back at a right angle, traversing in that part of its course the neural ring before expanding into the stomach. This cavity is, in most Spiders, produced into cæcal appendages, which, in some, extend into the basal joint of the cephalateral limbs. The bile-ducts open into that part of the intestine which traverses the thoracetron ('abdomen' of arachnologists). The proportion of difference to resemblance must be kept in mind when speculating on the degree of affinity of Xiphosura to Arachnida."

§ 4. "*Sanguiferous System.*—The dissection of *Limulus* was commenced from that aspect or plane of the body next to which, in Invertebrates, is the part of the neural axis called 'superœsophageal,' and which, as it supplies nerves to the organs of sense, answers to the brain in Fishes. As in these Vertebrates also, the removal of the neural or dorsal part of the skeleton exposes the vascular system analogous to the so-called 'aorta' of Fishes, and homologous with the 'dorsal vessel' in Insects. In *Limulus* the walls of this vasiform heart exhibit muscular and valvular structures, for the same purpose or office as those of the vertebrate 'heart.'

"In a specimen dissected, with a carapace, or upper crust of the two chief parts of the body, 9 inches in length, the heart was 4 inches 8 lines in length. It was included in a delicate membranous sac analogous to a pericardium, but forming, in fact, the wall of a venous sinus. This wall consists of two layers. One may be properly termed a 'tunic;' it includes extremely delicate fibres, chiefly transverse, but reticularly interwoven in a fine cellular bed, the inner surface of which has been the seat of formifaction, or vital crystallisation, of particles from the contained fluid, forming an epithelium,[1] the whole resembling a fine arachnoid membrane. The heart is fusiform, widest at its hinder third, gradually narrowing, transversely, to its fore end, which is 2½ inches from the fore part of the cephaletron, more rapidly contracting to its hind end, which is 1½ inch from the joint of the tail-spine. In the vertical diameter (Pl. XXXIV, fig. 1, *r*, *r*) the hinder contraction is more gradual.

"The heart-wall consisted of an outer, thin, smooth, compact coat, and a wall of striate muscular fibres consisting of a thin outer longitudinal layer, and a thicker transverse or circular series. The wider part of the heart shows traces of an epithelial lining due to the action initiated or invited by a surface in contact with the formifying material in solution. The arachnoid coat of the pericardial sinus is reflected over the outermost proper tunic of the heart, and is continued into the venous ostia where it gains thickness.

"These ostia are sixteen in number, arranged in seven pairs at the sides, but towards the dorsal surface, of the heart, with a terminal eighth pair. The hinder 'ostia' are rather nearer together than the others. The muscular tunic in the intervals of the ostia (Pl. XXXIV, fig. 1 *r*, *r*) is about a line in thickness, but thins off rapidly at the two ends of the heart. Each 'ostium' (ib., *o*, *o*) is provided with a pair of narrow semilunar valves, placed with the intermediate slit almost transversely to the axis of the cardiac tube.

"The foremost artery runs to the 'ocelli,' is there connected with, or seems to enclose, the nerve; it then bends down, following the curve of the carapace to the angle formed by the upper with the flat under surface of the digging shield, near which angle the artery is reflected backward and cannot be further traced as a distinct tube. On each side of the origin of the 'ocellar' artery arises one of double the size, which, diverging from its fellow, curves outward and downward over the fore-part of the intestinal canal (Pl. XXXIV, fig. 1, *s*); it gives off, in this course, a branch which ramifies upon the gizzard, a second to the intestine and liver, the main trunk being continued to the nervous annular centre (ib., *β*), where it expands, and combines with its fellow of the opposite side to form a sheath for that centre analogous to a 'dura mater.' This rather loose sheath is continued along the ganglionic ventral chord, and is prolonged, like a loose neurilemma, upon the nerves sent off therefrom, as it is upon those in connection with the annular centre.

"Fine size-injection being thrown into the 'heart' from behind forward appeared to give a rich display of arterial ramifications. But dissection showed that the contents of the seeming arteries ceased to be the simple injected matter where the 'gastric arches' (ib., *s*) reached the nervous ring (ib., β); for here the coats of the artery become thinned, the injection lining them as a thin flake of colouring matter, and, at the same time, covering a thinner membrane which formed the 'neurilemma' or chief layer of the delicate tunics of the nervous matter of the neural ring.[1] The same condition was presented by the seeming abdominal arterial trunk continued backward from the neur-arterial circle (Pl. XXXVI, *a*, B, to or of nerve *n* 19). On slitting open the coats of the blood-vessel and washing out the flake of injection, the ganglionic nervous chord was exposed in its interior.[2] The same result followed the like perquisition of the smaller ramifications of the vascular system into which the injection had penetrated, and engendered the conviction that the main pair of arteries had but a brief course as such,[3] becoming resolved on reaching the neural ring into blood-sinuses, a condition which prevails throughout a great proportion of the vascular system of *Limulus*. The whole nervous system, save where the terminal twigs are lost in the tissues, is bathed in the blood of these sinuses, which retain the appearance of ramified vessels, through their relations to the nerves as the vascular envelopes of these.[4] Elsewhere the sinuses expand, lose the character of tubes, or vessels, occupy the interspaces of viscera and muscles, initiate the ramified branchial system of vessels, and finally return the blood to the pericardial-like sinus enclosing the heart.

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[1] Owen, 'Anat. of Vertebrates,' vol. iii, p. 499.

" A pair of arteries is sent off near the anterior pair of ostia, and are closely connected with the much larger veins emptying the neighbouring sinus into the corresponding parts of the pericardial one. These arteries pass outward and forward, and subdivide into branches, which are lost upon the epimeral nerves. I was unable to distinguish an artery corresponding with the second osteal vein. This vein courses outward near the hind border of the cephaletron, bends forward, and runs parallel with the lateral or ocular ridge as far as the compound eye: its branches are short, and speedily expand into sinuses.[1] A pair of arteries are obscurely indicated arising near the last pair of 'ostia,' passing obliquely outward and backward. The posterior or pleonic artery (Pl. XXXIV, fig. 1 *t*) has more definite tunics and holds a longer course than those from the fore-part and sides of the heart. It is wavy at its beginning, in relation to the varying directions of the tail-spine, in its flexile movements upon the body. The artery having entered the body of the spine continues its course as such, along the dorsal side of the cavity, through two thirds of its length, then subdivides and blends with the sinuses continued from the ventral chord and investing the 'cauda equina' of the tail-spine.

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[1] " Preparation No. 1303 c, Physiol. Series, Mus. Coll. of Surgeons."

[2] " The neurine thus seems to be small in proportion to the thick neurilemma, as Gegenbaur remarks, but he did not recognise the share taken by the arterial tissues in this sheath :—' Bezüglich des feineren Baues soll die schon oben angeführte dicke Umhüllung des Schlundringes erwähnt werden, derzufolge der eigentliche Nerventheil des Schlundringes relativ klein erscheint,' op. cit., p. 241."

[3] " They are shown as cut off from the arches and lost upon the brain in Pl. XXXVI."

[4] " This interesting stage in the differentiation of nerves and vessels was demonstrated in my Hunterian lectures of 1852, 'Organisation of the Entomostraca illustrated in the Limulus,' Lecture XVI, *Crustacea*, 'Synopsis,' March, 1852, and is briefly enunciated in the volume on INVERTEBRATA as follows: —'The sides of the great œsophageal ring are united by two transverse commissural bands; but the most remarkable feature of the nervous axis of this Crustacean is its envelopment by an arterial trunk. A pair of aortæ from the fore part of the heart arch over each side of the stomach, and seem to terminate by intimately blending with the sides of the œsophageal nervous ring. They, in fact, expand upon and seem to form its neurilemma; a fine injection thrown into them coats the whole central mass of the nervous system with its red colour,' 'Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals,' by Prof. Owen, F.R.S. (2nd edit., London, 1855, Lecture XVI, p. 310). Gegenbaur, in his historical treatise on *Limulus* (op. cit., p. 241), remarks:—' Auch die peripherischen Nerven sind sämmtlich von einer dicken Hülle umgeben, die sogar noch makroskopisch erkennbar ist.' "

"The veins or venous sinuses with the least indefinite form are those that course along beneath the medilateral ridges of the cephaletron in association with the arteries, and those which follow and lie near the margins of both cephaletra and thoracetra. The latter return their blood by the posterior veins, united by the median channel with the pair in advance, their common trunk opening into the hind part of the pericardial sinus.

§ 5.—"*Respiratory System.*—The gills consist of thin membranous plates of a broad semi-oval shape; there are from 150 to 200 in each gill or group, the number diminishing in the hinder ones. The gills are in pairs, attached to the upper, hinder, or inner surface of the proximal joints or broad coalesced plates of the last five thoracetral limbs (IX—XIII, Pls. XXXIV and XXXV).

"The branchial plates overlap each other from before backward. The anterior and exterior one is the smallest; the others progressively increase to a little beyond the middle of the series; the hindmost again diminished, but in a less degree; the whole mass has the full oblong or irregular oval form shown in fig. 2, Pl. XXXVI. Each plate is strengthened by a chitinous filament along its free border, thickest where this is exposed, so that the length of the gill is greater at its free or floating side than along its attached base: the free margin is also ciliate.

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[1] That an arterial canal accompanies the vein is indicated by the course of the blood, as observed by Packard in a living larva of *Limulus*:—"I could not see the walls of any of the arteries; and, indeed, the arterial blood seemed to flow in channels exactly like the venous sinuses, as in the arteries which pass around the margin of the carapace the blood-disks were seen to pass by irregular currents towards the front edge of the margin. The anterior aorta could not be detected in the young *Limulus;* but on each side of the end of the heart the blood could be seen rushing out and in, and with a general course downwards beneath the œsophagus, while a current of blood flowed on each side of the stomach and œsophagus, and thence went out at a considerable angle to the edge of the carapace, where it divided, sending a branch under the ocelli, and another along the outer edge of the cephalic shield, and again subdivided opposite the second pair of cardiac valves, one current following the edge of the cephalo-thorax and the other going going on towards the heart. The abdominal arteries represented by powerful currents of blood issuing from between the last two pairs of cardiac valves are directed obliquely outwards and backwards. The caudal aorta sends a current nearly to the tip of the spine, the venous sinuses returning it along the sides. The simple arrows mark the course of the returning currents, which flow from all parts of the body towards the valves. 'Development of *Limulus polyphemus*,' pl. v, fig. 27, p. 171." This admirable memoir appeared subsequently to the reading of Prof. Owen's paper before the Linnean Society, and the report given of it in the number of 'Nature' for January 25th, 1872, is quoted by Dr. Packard at p. 201. Dr. Packard notes that the heart "beats ninety times a minute" in the larva after the first moult.

"Each gill-plate consists or two layers or membranes, united along the chitinous border, and also by numerous filaments, so far apart as to divide the interspace into reticular canals or cells, smallest at a subcentral space (fig. 3 *a*), and affecting a concentric arrangement as they approach the free borders of the gill-plate. The two constituent layers of the branchial plate may be regarded as productions or duplicatures of the delicate skin of the upper or inner surface of the lamelliform limb.

"From a venous sinus along the base of attachment of the gill-plates[1] the blood passes freely into the interlamellar spaces, whence it enters the vessels coursing along the border of each plate, from the inner side, where the vessel is largest, towards the outer side (Pl. XXXVI, fig. 2 *a*). Here appears to begin the returning system of branchial veins on the fore part of the base of attachment. These veins ascend and converge on each side of the intestine, and traverse the pericardial sinus to enter directly the heart by the five pairs of ostia at the widest posterior part of that organ.

"The muscles which divaricate the branchigerous limbs, and at the same time separate the gill-plates and expand their cavities to the extent permitted by the interposed columns, act as inspiratory ones, inviting the flow of blood from the abdominal sinuses into the cavities of the gill-plates. This action may be supposed to take place when the King-crab is moving or resting in its atmosphere of sea-water. The muscles which approximate the branchigerous plates and press them against each other and the thoracetron will close the ciliate slits leading to the gills, will compress those organs, and tend to squeeze the blood from the reticulate interspace of their constituent lamellæ. Such movement must be 'expiratory' and also effective in defending the delicate surfaces of the branchial membranes from the atmosphere of muddy or sandy sea-water when the King-crab is burrowing either for food or concealment.

§ 6.—"*Generative System.*—In *Limulus* the sexes are distinct;[2] the male is smaller than the female, and in both the generative organs lack those accessory parts that relate to intromission in some higher Crustaceans.

"The ovarium is a system of ramified tubes and cavities, occupying chiefly the dorsal region of the body; it extends along the median part of the thoracetron, and expands laterally in the cephaletron. Parts of the ovary are single and median, the rest consists of parial, symmetrical, lateral, ramified tubes, chiefly situated in the cephaletron.

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[1] "'Il paraît exister une libre communication entre ces diverses poches respiratoires; car, en introduisant de l'air dans une de ces duplicatures on voit non seulement s'écarter les lames de la même branchie, mais même se gonfler toutes les branchies, ainsi que l'espace membraneux entre les pattes abdominales,' J. van der Hoeven, op. cit., p. 19. The intercommunicating passage is the basal sinus, related to the gills, physiologically, as a 'branchial artery.'"

[2] [The separation of the sexes characterises the Crustacea generally, save in the aberrant Cirripedia, in which the greater part appear to be hermaphrodites.]

"The hindermost cavity (Pl. XXXV, fig. 6 *q*) is a longitudinal tube, commencing by a blind end above the rectum; it extends forward, expands, and bifurcates about the middle of the thoracetron; the branches at first diverge, then bend inwards and reunite, sending back into the interspace of the bifurcation a short blind sac. From the base of this heart-shaped portion the bifurcate tubes are continued forward, slightly diverging, leaving a mid-space for the heart and intestine, as they cross the articulation between the thoracetron and the cephaletron. About two inches in advance of the second bifurcation each tube expands laterally into a triangular cavity, from the outer and fore angles of which the ramified systems of the lateral loops, q'', are continued. A small branch is sent off from the outer side of the dilatation. Three or four tubes converge from its fore part, and anastomose[1] to form the anterior single symmetrical cavity, $q^{\times}$. This is oblong, subquadrate, subdepressed, and subreticulate. It is longitudinally channelled above by the fore part of the heart resting thereupon, this part of the ovary being interposed between the heart and intestines (Pl. XXXIV, figs. 1 and 2 *q*). It seems to have been developed in or from the last remnant of the including germ-mass. From the hinder and outer angles of the antero-median part of the ovary proceeds the tube, which passes outward and backward, joins that from the fore part of the lateral expansion, and curves outward and forward to meet and inosculate with a similar retrograde branch from the fore and outer angle of the antero-median lobe. From the outer side of these ovarian loops (Pl. XXXV, fig. 6 q'') proceed four or five branches, which interramify with the hepatic lobe. The branch tubes ($q^{\times}$) continue from the fore part of the antero-median sac, and its loops are continued, subdividing and reticularly anastomosing, along the sides of the gizzard to the fore part of the cephaletron.

"Each of the main parial oviductal canals, before converging to the anterior reunion, dilates and sends outward and backward a wide tube, which, after sending off, or rather receiving, three large tubes ($q^{\times\times}$), is continued backward as the common oviduct (Pl. XXXV, fig. 6 *o*, *o*). The hindermost of the three large tubes passes outward and backward to near the outer ends of the joint between the cephaletron and thoracetron, and there curves forward beneath the lateral cephaletral ridge, and receives the ova from the part of the ovary extending to the lateral margin of the cephaletral cavity. The foremost of the three branches collects the ova from the deeper seated interapodemal parts of the ovarium, the intermediate branch those from the dorsal level above and exterior to the apodemata.

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[1] "'Lectures on Invertebrata,' ed. 1855, p. 329, shown in *Maia*, in figs. 135, *a'*, *b'*. Anastomoses between the right and left system of ovarian tubes were noticed by Gegenbaur (loc. cit., p. 247), who well remarks on this evidence of crustacean affinity:—'Durch diese Verbindung beider Ovarialhälften reiht sich *Limulus* an viele andere Krustenthiere an, wogleichfals ein unpaarer Abschnitt der inneren Genitalorgane vorhanden ist.'"

"The numerical correspondence of the lateral tributaries to the main median or submedian receptacles of the ova with the neural indications of the segmental constitution of the two chief divisions of the body is less obvious than in those of the hepatic masses. This may be due to the later period of development of the genital factories.

"The part of the ramified ovarian system to which the term oviduct is here applied is the tube, *o*, continued from the common stem of the three last-described tubes, and passing backward, inward and downward, across the cephalo-thoracetral joint to the part of the upper or inner surface of the 'opercular' limb, viii, shown in fig. 6, Pl. XXXV. The termination here of the oviduct (*p*) was rather prominent; the outlet is transverse, and formed by tumid labia, with the inner surface transversely plicate.

"The bifurcation of the hind part of the ovary, before passing from the thoracetron to the cephaletron, relates mechanically to the accommodation of the cardiac and intestinal tubes during the frequent and forcible inflections of the two great body-chambers upon each other. The laden ovarium, instead of being pressed down upon the heart (as it would have been if it had been continued as a single median and vertically parallel viscus across the joint where the cephaletron was depressed at an angle with the thoracetron), slips, by its division, on each side of the heart during the inflection. A similar relation to convenience of package governs the forward extension of the ovarian bipartition in relation to the main parts of the heart and intestine.

"The most significant difference between the female organs of *Limulus*, and those of the higher or malacostracous, squat-eyed Crustaceans is the absence of the dilated part of the oviduct forming the copulatory pouch, or 'spermatheca,' which absence relates to there being no intromission in the act of impregnation in *Limulus*.

"In the male, the testes are ramified and subreticulate, like the ovaria, and occupy almost an equal extent of the two great cavities of the body. The sperm-ducts open upon a corresponding position of the opercular plate (Pl. XXXV, fig. 8 *p*), their termination being on a smaller but rather more prominent cone of thin yellow chitine, at the apex of which the sperm-tube terminates by a whitish bilabiate orifice (Pl. XXXV, fig. 7 *b*)."[1]

Whilst giving the foregoing description of the anatomy of *Limulus polyphemus* from the pen of Professor Owen,[2] we must not omit to record that, as early as 1838, Professor

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[1] Dr. Packard describes the spermatozoa as having a broad oval body, sometimes contracted before the anterior end, and posteriorly suddenly terminating in a filament about four times as long as the body. "On the Development of the *Limulus polyphemus*," 4to., 'Mem. Boston Soc. Nat. Hist.,' vol. ii, p. 156.

[2] 'Trans. Linn. Soc.,' 1873, vol. xxviii, pp. 459—506 (read December 21st, 1871, and January 18th, 1872). See also Owen's 'Lectures on the Comparative Anatomy of Invertebrata,' 1st edit., p. 181, 1843, and 2nd edit., pp. 319, 320, 1853.

J. Vander Hoeven had contributed a valuable memoir[1] on the sole other surviving representative of the XIPHOSURA, the *Limulus Moluccanus.*

An excellent account of the general anatomy of *Limulus polyphemus* will also be found in Professor Huxley's lectures on the Invertebrata[2] (1857). Professor Gegenbaur's researches on the anatomy of *Limulus* appeared a little later in 1858.[3]

The liberality of the French Government in publishing the results of researches carried out by the scientific expedition to Mexico in 1867 (although much delayed by the siege of Paris), enabled Professor Alphonse Milne-Edwards to produce in 1873[4] a monograph on the anatomy of *Limulus polyphemus* most admirably illustrated by twelve folio chromo-lithographic plates, which for colour and excellence leave little to be desired. We shall make further references to these memoirs as we proceed.

EXUVIATION AND REPLACEMENT OF LOST APPENDAGES.

We are indebted to the Rev. S. Lockwood, Ph.D., for a series of most valuable observations on the American "Horse-foot Crab," *Limulus polyphemus,* Latr., carried on at Rariton Bay, New Jersey, U. S. A.[5]

According to Dr. Lockwood, the exuviation of the King-crab is performed several times during the first year of its life, and at very short intervals, varying according to the time of hatching. Dr. Lockwood believes that the young Limuli which are hatched in the latter part of June will complete five or six moults before the winter sets in. Even in the case of the adult King-crab he thinks it probable that the shell is cast more than once in the year. He mentions the capture of an adult female *Limulus* in the Oyster Dredge, during a fine open February, in Rariton Bay, which had just shed its shell and was still quite soft. Like all other Crustacea it moults more frequently during the earlier and more rapid period of growth than afterwards.

Limulus being a great burrower he not unfrequently disturbs the bivalve Mollusca in their submarine retreats. Dr. Lockwood mentions an instance of a *Limulus* which had either accidentally trodden upon or had wilfully seized the projecting siphons of a

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[1] 'Recherches sur l'Histoire Naturelle et l'Anatomie des Limules,' 1838, Leyden, 4to, pp. 48, 7 plates.

[2] "Report of Lectures delivered at the Royal School of Mines," 'Medical Times and Gazette,' 1857, vol. xv, p. 188. See also his recently published volume, 'A Manual of the Anatomy of Invertebrated Animals,' small 8vo, London, 1877, pp. 700.

[3] Gegenbaur, "Anatomische Untersuchung eines Limulus, mit besonderer Berüksichtigung der Gewebe" ('Abhandl. d. Naturf. Gesellsh. zu Halle,' Bd. 4, Hefte 2 u. 3, 1858, p. 227).

[4] 'Études sur les Xiphosures et les Crustacés de la Région Mexicaine,' cinquième partie, Paris, folio (1873), pp. 44, 12 coloured plates.

[5] Communicated in October, 1869, to the 'New York Lyceum of Natural History,' and subsequently printed in July, 1870, in 'The American Naturalist,' vol. iv, No. 5, p. 257.

Venus mercenaria; the siphons were instantly withdrawn, and the less agile King-crab found himself next moment a prisoner with his limb nipped firmly between the valves of the outraged *Venus*. But here an important difference is noticeable between *Limulus* and an ordinary Crab or Lobster; had either of these been thus trapped by the leg, they would have speedily made good their escape by giving their body a violent jerk and leaving the imprisoned limb behind them, a cicatrix forming over the articulation for the lost limb, which after three or four moults would not only have been reproduced, but would have regained its normal size. It must, however, be borne in mind that the leg of a Decapod is not homologous with that of *Limulus*, whose organs of locomotion are modified palpi or maxillipeds rather than true feet, all its walking-appendages being mouth-organs at their proximal end, which would render their replacement in *Limulus* as difficult as would be that of the maxillæ or maxillipeds in a Decapod Crustacean, of the separate reparation of which we have no recorded instances.

The periodic exuviation of *Limulus* seems to be a very simple and expeditious process. "A thin narrow rim runs round the under side of the anterior portion of the cephalic shield. This is in fact the widest part of the animal. Just before the time for exuviating a separation occurs between this rim and the perimeter of the anterior shield. To the unaided eye this rent is altogether imperceptible, but it splits open on the exertions of the animal; and at this opening it emerges from its old shell. As the opening is in front and in the place of greatest width, and moreover as the shell is subcoriaceous and somewhat yielding, and at this particular place is very thin, *Limulus* enjoys in this respect a great advantage over the higher Crustacea, whose moult takes place by a separation between the posterior border of the carapace and the abdomen, and whose shell is composed of more unyielding materials.[1]

"The exuviation of the King-crab takes place several times during the first year, and at very short intervals. How many I do not know, as that must vary according to the time of hatching. But I think," says Dr. Lockwood, "the young produced in the latter part of June will accomplish five or six moults before the cold weather comes" (op. cit., p. 261).

The same author records the exuviation of a large female *Limulus*, which measured eight inches in the shorter diameter of its cephalic shield, but which after moulting was nine and a half inches when measured in the same direction. He justly observes, "if they moult more than once in the year, this would make their growth rapid; and if they do not, they must attain an age of not less than eight years before reaching the size that indicates adult life."

The same excellent naturalist observes, "every spring, as soon as the water has lost its winter temperature, large numbers of the young of the previous summer are found in the shallows. These range from an inch to two and a half inches in the shorter diameter. As the creature, when beginning life for itself, is scarcely a quarter of an inch in diameter, this would imply rapid growth, and I think that the larger of the above have probably lived through two winters" (op. cit., p. 262).

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[1] Op. cit., p. 257.

ON THE SPAWNING OF LIMULUS POLYPHEMUS.

From an actual experiment made by the Rev. Samuel Lockwood it would appear that the female King-crab spawns twice every year, the breeding-season extending over the months of May, June, and July. They come up during the great high tides, spawning under water near the line of high-water mark; thus the eggs are daily exposed to the sun's warmth for a short time at low water.

At this season they come up in great numbers in pairs, the male grasping the sides of the female's shield with his strong and peculiarly modified chelate antennæ.

The eggs, measuring fully half a pint in quantity, and about the size of millet seed, are deposited by the female in a hole in the sand, and are fecundated by the male *after deposition*, and then left to hatch.

This is unlike the behaviour of most of the Crustacea, which, as a rule, appear to fecundate the ova by a true union before the eggs are discharged from the ovaries.[1]

The eggs in the majority of the Crustacea are borne by the female either in an egg-pouch, or *marsupium,* formed by a modification of a certain number of pairs of the thoracic appendages, or adhering by a viscous secretion to the hairs of the abdominal feet (as in the Crab, Lobster and Prawn), until they are hatched.[2]

The ovipositing of *Limulus* may serve to explain the origin of the masses of fossil eggs met with in the shales of the Old Red Sandstone of Forfarshire and Trimpley, near Bewdley, Worcestershire, formerly called *Parka decipiens*, and now referred to *Pterygotus*,[3] for the Eurypterida, like the Xiphosura, may also have left their eggs in the shallows to hatch.

From the experiments of Dr. Lockwood it would appear that the eggs of *Limulus* are slow to hatch. Thus a batch which he preserved occupied seventy days after spawning before hatching; whilst some, set aside at the end of the season in a jar of salt water, hatched out *after some three hundred and fifty days* from the time of spawning.

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[1] To this rule there are some exceptions. In the ANOMOURA and MACROURA there are no copulatory pouches, and the vulvæ open on the basal joint of the third pair of ambulatory legs. It seems pretty certain, therefore, that in these forms the fecundation of the ova cannot take place until the eggs are actually extruded, as known to be the case in *Astacus fluviatilis* (see a paper by M. Chantran, 'Comptes Rendus,' 15th January, 1872:—"The female crayfish lies on her back, bending forward the tail, and making a hollow, into which the ova are passed, the male depositing the spermatozoa upon the plates of the tail-fan and on the plastron of the female, whose appendages seem coated with a greyish viscous fluid").

[2] *Squilla* is said to deposit them within her burrow; *Gegarcinus* deposits them below low-water line on the shore; *Apus*, *Artemia*, *Branchipus*, and *Daphnia* deposit them in the water; *Argulus* fixes her eggs to a stone at the bottom of the water, sometimes to the number of 1500 at once.

[3] See Part III of this 'Memoir,' Pl. XVI, figs. 10, 11.

He very justly estimates the rate of hatching to be due to the greater or less exposure to light and warmth and to the oxygenation effected by the constantly shifting tide-wave and the occasional exposure in damp sand or mud to the sun's rays at low water.

This exceeding vitality and fecundity may best explain the persistence of this genus in time, a persistence probably unsurpassed by any among the Crustacean class save the Entomostraca alone.

EMBRYOLOGY OF LIMULUS POLYPHEMUS.

So long ago as 1838 Professor H. Milne-Edwards[1] had examined the eggs of *Limulus* containing the young ones about to be hatched; he found that at this stage of their development they present very little difference in the conformation of the anterior portion of their body from that which exists in the adult; but the abdominal portion of the body bears only three pairs of appendages, and the long styliform tail-spine, so remarkable in the adult, does not exist at all; the form of the abdominal portion likewise is equally different at this epoch.

No further observations on the development of *Limulus* were made until the years 1869 and 1870, when the Rev. Samuel Lockwood, residing at Rariton Bay, New Jersey, U.S.A., communicated the results of a series of observations made on the "Horse-foot-crab" on that coast to the New York Lyceum of Natural History in October, 1869.[2]

Two valuable memoirs on the development of *Limulus polyphemus* have appeared (1) by Dr. Anton Dohrn,[3] 1871, (2) by Dr. A. S. Packard, jr.[4] (Preliminary paper 1870 and full memoir, 1872.)

We propose to quote chiefly from Dr. Packard's memoir as being the most recent, and also because he enjoyed greater facilities, both on account of frequent visits paid to the coast, and also by constant inter-communication with Dr. Lockwood residing at Rariton Bay, New Jersey, one of the regular resorts of the "Horse-foot-crab," as *Limulus* is there called. During the progress of Dr. Packard's investigations, which extended over two years,[1] he was supplied by Dr. Lockwood, in the Springs of 1870 and 1871, with numerous specimens of the freshly laid eggs of *Limulus* for examination, and he pays a well-earned tribute to the ardour and enthusiasm of this excellent naturalist to whose original observations we are greatly indebted for the present state of our knowledge of the early stages in the life of this remarkable Crustacean.

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[1] "Sur le Développement des Limules; Société Philomatique," extr. 'Proc. verb.,' pp. 125, 126; 'l'Institut,' vi, No. 258, 1838, p. 397.

[2] Since published with additional matter in the 'American Naturalist,' vol. iv, July, 1870, pp. 257—274.

[3] "Zur Embryologie und Morphologie des *Limulus polyphemus*;" von Dr. Anton Dohrn ('Jenaische Zeitschrift,' Band vi, Heft 4, p. 580, Tafeln xiv and xv), received September 30th, 1871.

[4] "On the Embryology of *Limulus polyphemus*," by A. S. Packard, jun., M.D. Read before the American Association for the Advancement of Science, August, 1870 ('American Naturalist,' vol. iv, No. 8, October, 1870, p. 498).

"The Development of *Limulus polyphemus*," by A. S. Packard, jun., M.D., read November 16th, 1870, 'Mem. Bost. Soc. Nat. Hist.,' vol. ii, 1872, pp. 155—202, 3 plates, 4to.

The freshly laid eggs of *Limulus* measure ·07 of an inch in diameter, and are green in colour.

The annexed figures (Woodcuts, fig. 74—77) introduce us to some of the earliest appearances presented by the ova observed under the microscope by Dr. A. S. Packard.

Earliest stages in the Embryology of the *Limulus polyphemus* (after Packard).[2]

FIG. 74.

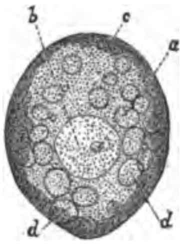

FIG. 74. Cell-egg, with yolk-cells developing. × 130 diams. *a*, the nucleolus; *b*, the nucleus; *c*, layer of protoplasm surrounding the nucleus (germ-yolk); *d*, *d*, yolk-cells developing.

Fig. 75.

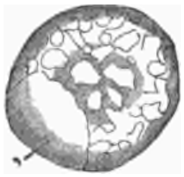

FIG. 75.—Portion of surface of freshly impregnated egg after the primitive cells have disappeared. × 30 diameters.

FIG. 76.

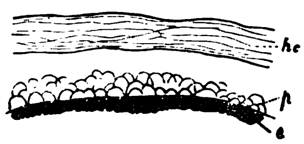

FIG. 76.—Portion of egg seen in section. *ch*, chorion; *p*, protoderm or amnion, not yet moulted; *e*, the blastoderm and yolk-cells. × 130 diameters.

FIG. 77.

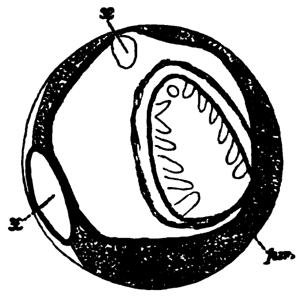

FIG. 77.—Early stage of embryo. *pm*, the amnion; *x*, *x*, yolk-masses detached before the formation of the blastodermic skin. [See also Pl. XXXIII, fig. 1.]

" We see in Fig. 74 the commencement of the formation in the cell-egg of a central mass of larger and denser granules constituting the nucleus (*b*) within which is the hyaline nucleolus (*a*). Round this is the mass of germ-yolk (*c*) in which are recognisable granules round other centres or yolk-cells (*a*).

After impregnation a denser aggregation of the blastodermic cells takes place on the surface (Fig. 75, *c*).

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[1] It is proper to mention here that Dr. Anton Dohrn, of Jena, first induced Dr. Packard to seek for the eggs of *Limulus* on the American coast. The specimens examined by Dr. Anton Dohrn, and which furnished the materials for his paper, were supplied to him by Dr. Packard. It is to be regretted that, owing to the distance at which Dr. Dohrn's studies were carried on, he could only examine specimens preserved in spirits, which prevented him from fully completing his researches. He has, however, added some valuable materials towards the completion of our knowledge of the embryology of *Limulus*, for which as well as for other valuable papers on the Arthropoda he deserves our best thanks.

[2] These four woodcuts, engraved for Prof. Owen's "Memoir," 'Trans. Linn. Soc.,' vol. xxviii, 1873, part iii, p. 488, have, with the author's approval, been most kindly lent for this work by the Council of the Linnean Society.

At this stage the periphery of the egg (Fig. 76) shows a separation of the external layer or blastodermic cells (*e*) into protoderm or amnion (*p*) and chorion (*ch*).

"So far as I am aware (writes Dr. Packard) *Apus* is the only other Crustacean in which a 'protoderm' like that of *Limulus* is formed. It is not comparable with the nauplian or larval skin, as it is composed of distinct cells and is entirely circular, with no lateral diverticula surrounding the appendages."

Fritz Müller has pointed out[1] that in some Isopoda (as for instance in *Philoscia*) the larval skin is not only without any folds or sac-like diverticula, but is closely applied to the egg-membrane.

Certainly when the embryo *Limulus* first appears its position is the same as in *Asellus*, *Ligia*, *Philoscia*, and other Isopods, *i. e.* with its ventral surface convex[2] (see Woodcut, fig. 77 and Pl. XXXIII, figs. 1 and 2).

The egg at this stage has two membranous envelopes, a dense inelastic 'chorion' and an inner elastic 'protoderm.'[3] This chorion remains entire so long as development is arrested or is sluggish, but as soon as the embryo increases in size, the tough inelastic chorion splits asunder, and the inner elastic protoderm enlarges, becomes dense, and vicariously fulfils the duties of the former.

Dr. Packard thinks that no particular taxonomic importance can be attached to the presence of this inner membrane, but that it is simply a biological matter having reference to the circumstances under which the eggs are deposited. He reminds us that the eggs of *Limulus* are laid loose in the sand and remain there, or are washed about by the waves during a month or six weeks, and possibly over a whole season.

In the case of *Apus* (whose ova are similarly provided with a chorion and protodermal envelope) the female lets her eggs fall at random to the bottom of the water, where they remain until hatched by the sun's warmth—a process which occupies two or three weeks. The chorion splits as in *Limulus*, and during the subsequent changes of the embryo the semi-transparent inner egg-membrane (' protoderm ') takes its place.

Whilst fully admitting the undoubted utility and fitness of this duplex envelope which, like the ephippial capsules of *Daphnia*, may have to undergo the severest trials in protecting the fertilised ovum within, often through protracted periods of delayed exclusion; it nevertheless seems only philosophical to homologise if possible these embryonal investments of the young of the several orders of Crustacea.. For although so ephemeral in their nature and varying in character according to the conditions under which the young are placed[4] they help us, as Claus, Darwin, Fritz Müller, and other carcinologists have shown, to bring together many of the aberrant members of the great Crustacean class, which are hopelessly isolated from one another in the adult state, but are at once recognisable in their larval dress.

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[1] 'Facts and Arguments for Darwin,' translated from the German by W. S. Dallas, F.L.S., London, 1869, 8vo, p. 71.

[2] H. Woodward, article "Crustacea," p. 649, vol. vi, 'Encyclopædia Britannica,' 9th edition, 4to, 1877.

[3] Dohrn calls the inner membrane in the egg of *Limulus* the "chorion," and the outer the "exochorion," but Packard's term *protoderm* appears preferable.

[4] Many of the Amphipoda and Isopoda display the most assiduous care for their young, and, like

The formation of the blastoderm accords with that of *Gammarus*, *Asellus*, &c., and also, according to Prof. Owen, with Arachnids, the yolk not undergoing segmentation.

§ 7. *Formation of the embryo.*—"Between one and two weeks after the eggs are laid (*impregnated?*) the primitive disk appears, bearing six pairs of appendages (see woodcut, fig. 77). The appendages become more prominent and in a day or two more appear as distinct tubercles." (See Pl. XXXIII, fig. 1.)

In the succeeding stage of development figured both by Drs. Dohrn and Packard (see Pl. XXXIII, fig. 2, after Packard), the oval body of the embryo has increased in size; the separation into cephalic and thoracico-abdominal divisions has taken place; the mouth-opening is seen, and the rudimentary six pairs of appendages are readily made out. The first pair are well marked by their position in front of the mouth and their minute size; in like manner the sixth pair are distinguished by their greater development and modified form. Dr. Dohrn also detects in this stage the under lip;[1] but his drawing does not show it very clearly. This is followed by the rudiments of the first thoracic plate bearing in the adult the ovaries, and marked in Dr. Dohrn's figure of the embryo by two pores. Behind these come the rudiments of the first two pairs of branchiferous plates not yet outspread. The abdomen is then, as afterwards, destitute of appendages. The 'arthomeres,' or body-rings, are also indicated beyond the areola, the sutures extending upwards but not reaching the dorsal side of the egg. These changes occur some time before the splitting apart of the chorion. The cephalic feet have increased in length and are folded upon themselves. To this period of development Dr. Packard has given the name of the subzoëal stage.

In another egg (Pl. XXXIII, figs. 3 and 4), the chorion of which had not yet split apart, the six cephalic and nine thoracico-abdominal segments are well seen, the sutures forming deep depressions in the yolk, which is pale green as before, and lobulated just within the integument. The bases of the limbs are nearer together, and the line between the cephalic and thoracico-abdominal segments may be distinctly seen, the posterior edge of the former projecting out sensibly beyond the sides of the abdomen. The two basal pairs of abdominal feet (*h g*) have become more prominent, being thinner and more lamelliform, the third pair (*i*) being still minute.

Referring to the early stages of the embryo of *Limulus* (Woodcut, fig. 77, and

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Mysis, are provided with a marsupium, in which the larvæ undergo their metamorphosis; and the offspring often pass a considerable time after attaining the perfect state. In these orders we find the young issue from the egg in a far more helpless and immature condition than in *Limulus* and some other Crustacea whose eggs are abandoned by the parents, reminding one very forcibly of the similar disparity of development in the young of Insessorial as compared with Rasorial and Natatorial birds.

[1] "Metastoma," H. W., "chilarium," Owen.

Pl. XXXIII, figs. 1 and 2) Dr. Packard compares it with the free-swimming "nauplius" condition of Entomostraca, especially of the Copepoda. He admits, however, that the differences are very great, and that probably other observers will not share this opinion.[1]

The stage which follows (see Pl. XXXIII, figs. 3, 4, and 5, copied from Packard) is distinguished by the differentiation of the thoracico-abdominal series, and the appearance of a third pair of rudimentary thoracic limbs, together with the first indications of the chelæ. The compound eyes are also seen as two white dots on the third segment of the cephalon. The ocelli appear still later and are situated near the centre of the anterior border. The nine thoracico-abdominal rings are indicated, no more being added during after life. There are six cephalic rings, indicated by deep emarginations on the head-shield, reaching even to the glabella. The whole body in the embryo is spherical, being as thick through as it is wide. "At this stage the chorion bursts open, the protoderm increases greatly in size, aad a corresponding amount of sea water is absorbed (by endosmosis) in which the embryo floats."

Dr. Packard observed this larval skin moulted, the process occupying two or more days owing to the want of aëration in the water, and the consequent sluggish condition of the embryo. The skin was pulled off from before backwards, and might afterwards be seen floating about in the protodermic fluid or entangled in the limbs of the embryo.

He at first believed this to be a 'nauplius' moult, but was subsequently led to consider it as analogous to the third moult in *Asellus*, described by van Beneden[2] in his Memoir on that genus. Prof. van Beneden has also pointed out that certain Anchorellæ and some Lerneopoda, after undergoing a first or blastodermic moult, accomplish a second or nauplian moult, which occurs when the embryo is provided with three pairs of appendages characteristic of the form of "Nauplius." This corresponds, he thinks, to the larval skin of *Ligia* and the nauplius skin of *Mysis*.

"In this second cuticle the embryo continues to develop, and we see a series of six pairs of appendages make their appearance in the Anchorellæ and five in the Lernæopoda. It then secretes a third skin which is the cyclopean or zoëal skin, and the young *Anchorella* and Lerneopod come into the world under this form (op. cit., p. 166).

As the young *Limulus* increases in size the yolk is gradually absorbed, and the body becomes flatter and expands laterally; the cephalic shield increases in breadth, and the hinder body is curved upon the cephalon, the larva assuming the position of an Amphipod in the egg, with its dorsal surface convex instead of its ventral surface, which is now concave. This stage, described by Packard, may probably be that figured by Dr. Dohrn, and copied by us from his memoir (see Pl. XXXIII, fig. 9). In this figure the differentiation of the articuli of the limbs has proceeded further than in fig. 4, the opercular and first and second thoracic branchial plates (*op.*, *br.*) and the rudimentary 'metastomata' or 'chilaria' (*ch.*) are also discernible, and the chelæ some free, others still apparently enclosed at their ends in the simple finger-tips of the previous moult.

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[1] We have elsewhere observed that "the greatest caution should be exercised in instituting comparisons between the so-called 'nauplius' and 'zoëal' stages of any one Crustacean when such stages are passed *within* the egg and those of any other Crustacean whose young (as in the Copepoda) actually pass through such stages *after they have quitted the egg*.

"In the Decapoda we know of only one instance in which the young appears as a free-swimming 'nauplius;' in the majority we see only the 'zoëal' and 'larval' stages; in some even the zoëal stage is overleaped, and the young appears as a larva differing but little from the parent."—['Encyclop. Brit.,' 9th edition, 1877, article "Crustacea," by H. Woodward, vol. vi, p. 650.]

[2] "Recherches sur l'Embryologénie des Crustacés. 1. Observations sur le Développement de *l'Asellus aquaticus*," 'Bulletins de l'Académie Royale des Sciences, etc. Belgique,' 2me série, tom. xxviii, 1869, p. 54.

Lastly, just before hatching, what Dr. Packard calls "the trilobitic shape" (Pl. XXXIII, figs. 6, 7, and 8) is assumed. This stage is peculiarly interesting to the palæontologist as well as to the embryologist as illustrating some points in the structure of the extinct members of the order not seen in the fully developed living King-crabs. Thus, in the deeply-emarginated head-shield of young *Limulus* at this stage, one is led to recall the indication of segmentation in the cephalon of *Hemiaspis* (see Woodcut, figs. 64 and 68, p. 178). We are also furnished with a means of interpreting the curious punctate or digitate structure of the margin of the head-shield in *Trinucleus concentricus* (see Pl. XXXII, figs. 38—41). The late Mr. J. W. Salter[1] supposed that the membranous margin of the head-shield of *Trinucleus* was once entire, "then became plicate, then perforate, and lastly separated into linear processes" (fig. 40 *l*). It appears to us more in accordance with the observed mode of evolution of the head-shield in larval *Limulus* (Pl. XXXIII, figs. 4, 6, 7, 12) to conclude that the margin of the head-shield in *Trinucleus* was originally digitate, then gradually closed up, leaving only perforations along the sutures in some, and only plicæ in others.

We have an analogous modification of the shells of certain Mollusca, *e.g.*, *Haliotis*, *Scissurella*, and *Pleurotomaria*, in which a slit becomes partially or wholly closed, leaving a furrow with perforations at intervals. It must be borne in mind that in these Gasteropods the structure referred to is connected with the respiratory functions, but in *Limulus*, *Hemiaspis*, and *Trinucleus* it indicates the margins of the primitive segments which have coalesced to form the cephalic shield.[2]

This trilobite stage of larval *Limulus* proves, if further evidence were wanting, that the front shield of *Limulus* is the head (cephalon), and *not the cephalothorax* (as erroneously called by Dr. Packard). In this view I am in accord with Professors Owen and Huxley, Mr. C. Spence-Bate, and other carcinologists.[3]

In like manner the hinder-body of the young King-crab (Pl. XXXIII, figs. 6 and 12) at this period serves admirably to illustrate the adult *Limuli* of palæozoic times.

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[1] 'Quart. Journ. Geol. Soc.,' vol. iii, 1847, p. 252.

[2] H. Woodward, article "Crustacea," 'Encyclop. Brit.,' 9th edition, 1877, vol. vi, p. 650.

[3] See "Further Remarks on the Relationship of the Xiphosura to the Eurypterida and to the Trilobita and Arachnida," by H. Woodward, 'Quart. Journ. Geol. Soc.,' 1872, vol. xxviii, pp. 46—63.

In the trilobed character of the body-rings with freedom of movement between each of the several segments we see recalled to life its remote ancestors *Neolimulus* of the Silurian epoch (Pl. XXXI, fig. 8), and *Bellinurus* (Pl. XXXI, figs. 1, 3, 4) of the Coal period. The presence of nine segments lends further confirmation to the correctness of our views, already so often expressed in the earlier parts of this Monograph and elsewhere, that we have evidence here not only of the entire thoracic series, but also of a rudimentary abdomen of which the ninth (the telson) represents the hinder somites arrested in their development, as indicated by the like condition of the post-thoracic series in *Hemiaspis* (see Woodcut, fig. 64, p. 177), and in the tendency to divide up into segments seen in the telson of *Stylonurus* (see Woodcut, fig. 73, p. 200).

" The trilobate character of the surface of the body, says Dr. Packard, is very marked, the cardiac or median region being considerably raised above the sides and on the thorax and abdomen; the sutures do not run continuously across the tergum, but are interrupted at the edge of the cardiac region, thus making the latter more distinct. The sutures between the segments are sinuate, as in the trilobites. The outer edge of each segment is convex, the convexity being greatest on the hinder portion of the edge as in the Trilobites. The branchigerous thoracic feet are still very small, and the median sinus between each is greater in the first than in the second pair. The maxillipeds are much as in the larva, the coxal joint being furnished with a stout spine directed inwards; but it is not until after several moults that the numerous spines which form the masticating surface appear.

" The chelæ are acute and long, the six spatulate spines on the penultimate joint of the sixth pair in the adult being now represented by simple spines, and the terminal forceps being quite complete.

" Just behind the last pair of maxillipeds are a pair of oval rather flat tubercles; their bases are united on the median line of the body, thence diverging outwards. These tubercles do not appear much before this period of the life of the embryo. They have no connection with the last pair of maxillipeds, nor can they be, as Savigny supposed, the rudiments of a seventh pair of legs, otherwise they would have appeared earlier in embryonic life. They are seen in Figs. 8, 9, and 11 (*ch.*), Pl. XXXIII, closing up the posterior end of the oral groove.

" In adult life they are movable at their bases and armed on their inner side with recurved spines, like those upon the maxillipeds; hence they serve the purpose of completing the circumoral armature, and also of retaining the food undergoing trituration preparatory to deglutition. Savigny considered them to form a sort of inferior lip." We are in accord with Professors Huxley, Hall, Owen, and others in considering these as the homologue of the broad heart-shaped metastoma or post-oral plate (Woodcut, fig. 71, p. 180) which closes the buccal aperture behind in the Eurypterida (see Parts I—IV of this Monograph).

Its great development in *Pterygotus* seems correlated with the difference in the form and functions of its jaw-feet as compared with those of *Limulus*.

"The ocelli are situated, in an earlier period of this stage than that represented by fig. 6, on the underside of the head just in advance of the mandibles, and are at this time white and irregular in shape, being a little longer than broad. A little later they appear on each angle of the front edge of the cephalon, the edge being afterwards expanded and extended, so that, as in fig. 6, they are placed a little way in from the edge. The eyes also are at first rounded white tubercles, becoming in more advanced specimens black along the front edge. The protoderm measures at this period ·13 of an inch in diameter. Of the eggs laid in the middle of May one was hatched June 30th, the majority came out of the egg about the 14th July, and the remainder kept hatching until the last of September in my jar. In the succeeding summer (July, 1871) the hatching jar, in which the water had remained unchanged since the previous October, and with no weeds to oxygenate the water, contained several embryos in eggs laid during the preceding year, in different though advanced stages of development, and also several larvæ hatched during 1870, though in a torpid state, due probably to the little air in the water. I much doubt whether the eggs of any other living Crustacean would show as much vitality. It should also be noticed that those eggs had not probably grown during the winter, but remained as it were in a state of suspended animation from October to July, a period of nine months. These facts confirm the remarkable observations of Rev. Dr. Lockwood on the wonderful vitality of the eggs of *Limulus*."[1] (See *ante*, p. 213.)

There is a considerable difference (probably due to age) between Dr. Dohrn's 'Trilobiten-Stadium' (see Pl. XXXIII, fig. 12) and that so called by Dr. Packard (Pl. XXXIII, fig. 6). Dr. Dohrn's figure agrees better with Dr. Packard's later stage, the freshly hatched young (Pl. XXXIII, figs. 10 and 11). The segmentation in the cephalon of fig. 12 has entirely disappeared, although the hinder body is still distinctly segmented, and the segments were no doubt to some extent movable. In fig. 10 (copied from Dr. Packard) the division of the hinder body into segments is obliterated save along the central axis.

In its earlier stages the young *Limulus* can fold its posterior segments under its head-shield, and when it at last quits the egg, before having undergone the first moult subsequent to hatching, it is very lively, walking over the jar, and burrowing in the sand at the bottom and occasionally swimming to the top, or skimming obliquely over the bottom by vigorous strokes of its thoracic feet. Mr. Alexander Agassiz once captured a specimen swimming on the surface three miles from shore. This fact indicates that this species owes its wide range, from Maine to the Gulf of Mexico and the West Indies, to the swimming habits of the larvæ.

The principal differences from the embryo just before leaving the egg are these:—the thoracico-abdominal shield is larger than the cephalic one; the sinuate sutures defining the segments of the post-cephalic somites are nearly obsolete, and the hepatic lobes which gave so strongly-marked a character to the head-shield in figs. 4, 6, and 7,

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[1] A. S. Packard, junr., op. cit., p. 168.

Pl. XXXIII, do not reach so near the edge of the carapace and cease to affect it by the appearance of sutures on the surface. The edge of the head-shield is fringed with hairs.

The edge of each segment of the thoracico-abdominal somites is toothed, the basal tooth being the largest, the succeeding ones more minute, and with a movable spine inserted on the posterior border of each serration and projecting beyond it (see figs. 10, 11 and 12, T, A, Pl. XXXIII). The border of these somites is also fringed with minute hairs.

APPEARANCE OF YOUNG LIMULUS AFTER THE FIRST MOULT.

The first moult observed by Dr. Packard occurred about the 25th of July, three weeks after hatching. The principal changes are the possession of a short abdominal spine, the origin of a fourth pair of thoracic branchigerous lamellæ, and the appearance of additional joints to the opercular plates, and the smaller and more numerous lobes of the liver.

Regarding the age of sexual maturity, and the period when the external male characters appear, Dr. Lockwood thinks that the time of puberty cannot come before the third or fourth year, and considers that the latter figure may prove the minimum. It is not until this period is reached that "the male undergoes its last metamorphosis." It then moults, and the antennal claws assume the peculiar shape of that sex[1] (see Pl. IX, fig. 1 *a*).

THE ZOOLOGICAL POSITION OF LIMULUS CONSIDERED.

Having briefly described the larval stages of *Limulus* I will pass at once to the conclusions arrived at as to the position of *Limulus* with regard to the other Crustacea.

Whether *Limulus* does or does not descend from a Nauplius, Dr. Dohrn considers that at present we have no knowledge of a Nauplius-stage in that genus, any more than in the Trilobita; but the subsequent stages agree with such forms as *Trinucleus* and *Sao*, in the gradual development of the young from a form having a simple cephalic and caudal plate to the adult stage in which numerous intermediate body-rings have been added. Dr. Dohrn further concludes that *Limulus* cannot be retained among the Crustacea, for two reasons. 1st. Because of the presence of only one pair of extremities which are supplied with nerves from the supraœsophageal ganglion.[2] 2ndly. From the position and form of the under lip.

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[1] When adult, the males in *Limulus moluccanus* have the chelæ of both the 2nd and 3rd pair of appendages modified, so as to form powerful recurved monodactylous claws, which shut against a projection from the penultimate joint. (Vander Hoeven, *op. cit.*, pl. i, fig. 3.)

[2] This was first asserted by Vander Hoeven in his 'Recherches sur l'Histoire Naturelle et l'Anatomie des Limules,' 1838.

1. "Bearing in mind that *all Crustacea* have two pairs of antennæ receiving nerves from the supracœsophageal ganglion, thus distinguishing them from the Spiders, Myriopoda, and Insects, it is (says Dr. Dohrn) impossible to ignore that the presence of only one pair of extremities (the antennules) in *Limulus* so supplied with nerves separates it from the Crustacea. And, further, to which of the two pairs of antennæ, and therefore to which of the two anterior pairs of extremities, in Nauplius does this first pair in *Limulus* correspond?" "This question," he adds, "we must leave entirely unanswered, as we have at least hitherto been unable to detect any trace of a rudimentary second pair either before or behind this first pair."

Dr. Dohrn therefore concludes that *Limulus* cannot be retained with the Crustacea, but must be classed with Spiders and Insects which have only one pair of antennæ.

2. With regard to the under lip (metastoma) Dr. Dohrn says that in all the Crustacea it is a fold of the germinal membrane behind the mouth. It is found on a level with the mandibles, or sometimes even in front of them. In *Limulus* the under lip is *behind* the sixth pair of appendages, and is divided into two parts.

This led Dr. Dohrn to suspect that it might prove to be really *a seventh pair of appendages;* but this point he has been unable to clear up; for, owing to the fact of his specimens having been preserved in spirit, he could not satisfactorily make out whether or not it has a separate nerve-ganglion. He, however, concludes that "these two peculiarities make it improbable that *Limulus* belongs to the Crustacea."

Dr. Dohrn remarks that "what Savigny has hinted at, and what Strauss-Dürckheim has one-sidedly expressed, reappears now under the light of the theory of evolution. The connection of the Arachnida with the Crustacea is probably through *Limulus* and the Eurypterida," as indicated by myself in 1866 (see 'Quart. Journ. Geol. Soc.,' vol. xxiii, p. 35).

In comparing the *Limuli* and *Eurypteri* with the Arachnida one naturally turns to the Scorpionidæ as the group most suitable for that purpose.

Both in *Pterygotus* and *Scorpio* we find the antennary system modified in the same manner, not only in form but in function also; the larval ocelli are seen in both; the locomotory appendages are all cephalic in both; and the elongated body, with its peculiar trapezoidal head-shield, its enlarged thoracic segments (the first in both) bearing the reproductive organs on the underside, and the more slender abdominal series followed by a broad apiculate tail-joint, naturally seems to invite a comparison of the two groups. But the respiration in the former is performed aërially by pulmonary sacs, arranged in pairs along the ventral borders of the thoracic segments; whereas in *Limulus* and *Pterygotus* the respiration is performed by branchiæ borne on the same series of segments (the thoracic) in *Limulus*, and by one or two only of the same in *Pterygotus*. But, on the other hand, the great cordiform under lip of *Pterygotus* and the two pieces homologous therewith in *Limulus*, the broad thoracic plate or operculum in both *Limulus* and *Pterygotus*, and also the large compound eyes and the respiratory system in both, differ entirely from any structure to be found amongst existing forms of Arachnida. I long held the opinion that the organs called combs in the Scorpion were homologous with the branchial leaves of *Pterygotus:* they are, so far as I am aware, aborted organs in *Scorpio*, although they are supposed to fulfil some excitatory function in connection with the impregnation of the ovaries: may they not probably be homologous with the opercular plates of *Limulus* covering the branchial plates, and bearing the orifices of the reproductive organs on their inner surface?

As I have elsewhere stated, there is no insuperable difficulty in accepting, on sound physiological grounds, the possibility of any animal passing through larval conditions, casting aside at even a single moult its branchiæ, and assuming aërial respiration, quitting the water and inhabiting the land, changing its element, its diet, its mode of progression, and its entire life. Such cases are familiar to the entomologist,[1] the carcinologist,[2] and even to the herpetologist.[3]

From his examination of the embryonal changes of *Limulus* Dr. Dohrn has been led to observe how remarkably the young stages agree with the youthful *Sao hirsuta* and *Trinucleus ornatus;* indeed, he might well add, with the young of *Agnostus*, *Aulacopleura*, *Phacops*, *Hydrocephalus*, and with every Trilobite of whose infancy the researches of the illustrious Barrande has made us acquainted (see Pl. XXXII).

He also notices the remarkable analogy which the nearly mature embryo presents to *Bellinurus* and *Prestwichia*—a resemblance which I had previously pointed out in my paper already referred to ('Quart. Journ. Geol. Soc.,' 1866, vol. xxiii, pp. 34—35).

I will now quote the final paragraph from Dr. Dohrn's paper, and then give my reasons for dissenting from his conclusions.

"The more the theory of evolution is allowed a direct influence in zoological work, the more conspicuous is its pre-eminently practical character, inasmuch as it not only solves problems, but also suggests a correct method of inquiry. Thus, it is true, it destroys the traditional system; but it sets up a new one immediately; and thus, if we ask for the result of its application as made in the present memoir, we arrive at the following conclusions:

"*Limulus* is most nearly related to the Gigantostraca; both seem to be related to the Trilobites, although it is not possible to demonstrate all the details of their relationship. The morphologico-genealogical relations of these three families to the Crustacea cannot at present be established, and perhaps may always remain doubtful. It is also impossible at present to say anything definite concerning the relationship between them and the Arachnida. Therefore all we can do is to combine these three families under a common name, for which I would propose Häckel's expression 'Gigantostraca,' and to place them in the system beside the Crustacea."

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[1] Larval and adult *Libellulæ*, *Ephemera*, &c.

[2] *Gecarcinus ruricola* and other Land-crabs.

[3] The Batrachia.

[4] Prof. Häckel believes the Trilobites to be a suborder of the Phyllopoda, from which, *perhaps*, the Pœcilopoda descended. He again divides the Pœcilopoda into two legions, viz. the Xiphosura and Gigantostraca. (See his 'Generelle Morphologie,' the Gigantostraca being *Pterygotus*, *Eurypterus*, &c.) In this view Gegenbaur agrees with Häckel.

To conclude, then:

According to Dr. Packard there is a Nauplius-stage passed by *Limulus* in the egg. (He, however, does not seem quite to understand what is meant by a Naupliform larva.) He admits that it is not like the "Nauplius" of *Apus* or of *Branchipus*, but is to be compared rather to that of the Trilobites, a knowledge of which we do not possess.

If *Limulus* is brought *nearer* to Trilobita through the discovery of the specimens of *Asaphus* by the late Mr. E. Billings, F.G.S. (figured in 'Quart. Journ. Geol. Soc.,' 1870, vol. xxvi, p. 479, pls. xxxi and xxxii), we have failed to understand its nature. The specimen is believed to possess *eight* pairs of five-jointed walking-feet attached to the movable thoracic segments of the body, not a series of mouth-feet (gnathopodites), as in *Limulus*, but rather like the thoracic legs in the Isopoda.

That which really does bring the Trilobites near to *Limulus* is the series of embryonal changes passed through by the latter in the egg, which resemble the young of the former, and also the young state in the Ispoda.

Thanks to Professor Owen, I am now in a position to rebut Vander Hoeven's and Dr. Dohrn's arguments as to the presence of only one pair of anterior extremities supplied with nerves from the supraœsophageal ganglion, and to show by the admirable series of dissections of the nerves drawn on Pls. XXXIV, XXXV, and XXXVI (reproduced from Professor Owen's Monograph), that, as in other Crustacea, *Limulus* possesses two distinct pairs of appendages (antennules and antennæ) which derive their neuration from two pairs of nerves arising from the front of the supraœsophageal ganglion. Van der Hoeven's statement must therefore be considered as incorrect.

He further confirms the statement made by me ('Quart. Journ. Geol. Soc.,' 1866, vol. xxiii, p. 33), that the thoracic or opercular plate derives its innervation from a cephalic ganglion, whereas the succeeding inner posterior branchigerous plates are appendages of the thoracic somites.

Concerning the Eurypterida, so far as our present knowledge extends, I must adhere to my already published conclusion, namely, that one pair of antennary organs is suppressed[1]—a strong argument in favour of the theory of the retention of larval characters by these palæozoic forms.

With regard to the under lip (*metastoma*), it seems singular to base the refusal of a place to *Limulus* among the Crustacea upon the fact that the metastoma is rudimentary, whereas in *Pterygotus* it is very large, formed in one piece, having a ridge in the mesial line. In the Trilobita it is wanting, and in place of it we have a largely developed hypostome, or upper lip, fulfilling the function of assisting the maxillæ to retain the food in the same manner as does the hypostome in *Apus*. Yet the Trilobita and Eurypterida (one with a hypostome, and the other with a metastome) are placed by Dr. Dohrn together in one section, *beside* the Crustacea. The development of this very organ in larval *Limulus* was one of the points which Dr. Dohrn was unable to clear up.

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[1] According to Spence Bate and Fritz Müller the second pair of antennæ are absent in the females of *Brachyscelus*, although the male possesses them like other Amphipods.

As to Dr. Dohrn's proposal to remove the Merostomata and the Trilobita from the Crustacea and place them in a separate class beside the Crustacea, and to include with them the Arachnida, I have made elsewhere[1] the following remarks:

"It is no difficult matter to pull down a system of classification; but it is only right to demand that this should not be done upon insufficient grounds.

"Heretofore, in the formation of zoological groups, it had been the custom (long before embryology became so important a branch of study, or was so well understood as it is at this day) to take the sum of all the characters which the species presented, giving due value and weight to each; and this method has been adhered to in the classification both of the animal and the vegetable kingdom by all our leading naturalists.

"The introduction of embryological investigations has furnished an additional and conclusive support in most cases to the results of the exhaustive method of examination already applied to the adult form, seldom aiding us so much in differentiating group from group as in pointing out affinities, and thereby inviting us to throw down boundaries (hitherto scrupulously guarded by the systematic naturalist) and to merge together larger and yet larger groups.

"Before this is done all I would beg is, that the facts and evidences for maintaining the existing arrangement may be carefully reconsidered.

"If we are contented to conclude with Dr. Dohrn that 'the morphologico-genealogical relations of these three families of Crustacea (viz. Limulida, Eurypterida, and Trilobita) cannot at present be established, perhaps may always remain doubtful,' and that we should therefore combine them under one collective name, '*Gigantostraca*,' placing them 'beside' the Crustacea, we lay ourselves open to the grave charge of destroying an established system without" offering any good ground for "setting up a new one in its stead.

"Take away the Trilobita from the pedigree of the Crustacea, and I submit that one of the main arguments in favour of evolution to be derived from the class, so far from being strengthened, is destroyed. From what are the Crustacea of to-day derived? Are we to assume that they are all descended from the Phyllopods and Ostracods—the only two remaining orders whose life-history is conterminous with that of the Trilobita? Or are we to assume that the Arachnida are the older class?

"'If,' as Fritz Müller well observes, 'all the classes of the Arthropoda (Crustacea, Insecta, Myriopoda, and Arachnida) are indeed all branches of a common stem (and of this there can scarcely be a doubt), it is evident that the water-inhabiting and water-breathing Crustacea must be regarded as the original stem from which the other (terrestrial) classes, with their tracheal respiration, have branched off.' "[1]

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[1] 'Quart. Journ. Geol. Soc.,' 1871, vol. xxviii, p. 59.

As regards the near relationship between the aquatic gill-bearing Xiphosura and Eurypterida, and the terrestrial tracheated Arachnida, we must bear in mind that the rich deposits of the Carboniferous period in Europe and America have yielded numerous examples of both these types. Scorpions and Spiders, differing but little from existing forms, flourished in the Coal-period, and *Eurypterus,* as well as *Limulus,* still survived from Silurian times.

While fully admitting the probability of a common ancestry for the *Scorpionidæ* and the *Eurypterida* we cannot pretend to say that the diverging point is reached at which the latter cast off its aquatic existence and commenced its terrestrial phase as an Arachnid.

Neolimulus, again, is a true Limuloid form, and it occurs as far back in time as *Pterygotus,* or nearly so; and *Hemiaspis,* one of the few intermediate forms met with, presenting characters between the long and the short-bodied divisions of the Merostomata, occurs also in the Silurian strata with *Pterygotus* and *Eurypterus.*

The Trilobita, with a far more remote ancestry than the Merostomata, only end in the Carboniferous period; whilst the Isopoda, with which I have ventured to compare them, have been traced back as far as the Devonian.

By placing in a tabular form the sum of the characters of each order side by side, we are the better able to comprehend the extent to which they are capable of being paralleled; and certainly it seems as if the verdict were in favour of as near a relationship existing between the Isopoda and Trilobita as that which undoubtedly does exist between the Xiphosura and the Eurypterida.

I.

Pterygotus (fossil extinct).	Limulus (fossil and living).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
2. Ocelli distinctly seen.	2. Ocelli distinctly seen.
3. All the limbs serving as mouth-organs.	3. All the limbs serving as mouth-organs.
4. Metastoma, *large,* bilobate, oval.	4. Metastoma small, bifid.
5. *Anterior* thoracic segments bearing either branchiæ or reproductive organs.	5. *All* the thoracic segments bearing either branchiæ or reproductive organs.
6. Other segments destitute of any appendages.	6. Other segments destitute of any appendages.
7. Thoracic segments *non-anchylosed.*	7. Thoracic segments *anchylosed.*[2]
8. Abdominal segments *free and well developed.*	8. Abdominal segments *anchylosed and rudimentary.*

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[1] 'Facts and Arguments for Darwin,' by Fritz Müller, with additions by the author. Translated from the German by W. S. Dallas, F.L.S. (p. 120).

[2] Free and movable in the very young state, and probably also in some of the palæozoic species, *e. g., Bellinurus* and *Neolimulus.*

II.

TRILOBITA (fossil extinct).	ISOPODA (fossil and living).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
(2. No ocelli.)	(2. No ocelli.)
3. Hypostome *well developed.*	3. Hypostome *small.*
4. (Appendages partly oral, partly ambulatory or natatory, arranged in pairs.)[1]	4. Appendages partly oral, partly ambulatory or natatory, arranged in pairs.
5. Thoracic segments, *variable in number from six even to twenty-six,* free and movable (animal sometimes rolling in a ball).	5. Thoracic segments, *usually seven,* free and movable (animal sometimes rolling in a ball).
6. Abdominal somites coalesced, forming broad caudal shield (bearing the branchiæ beneath).	6. Abdominal somites coalesced, forming broad caudal shield, bearing the branchiæ beneath.

A few words are necessary in explanation as to some points of dissidence between the conclusions arrived at by my friend Dr. A. S. Packard, jr., and myself.

Dr. Packard evidently relies *mainly* on embryology in deciding the zoological position which an animal shall occupy, a line of reasoning which I have felt it my duty on a former occasion most earnestly to deprecate.

Admitting, as I do, most thoroughly the great value of such researches, I nevertheless hold that it is essential to a correct interpretation of an organism to take the sum of all the characters which the species presents, giving due weight to each[2]—a method of investigation in which all our most sound and philosophical naturalists and physiologists are agreed.

1st. As to the comparison between larval *Limulus* and the *Trilobita,* I would observe that before *Limulus* leaves the egg—nay, even when the embryo is little more than a primitive band or disk traced out on the yolk (see woodcut, fig. 77 and Pl. XXXIII, fig. 1), it has *six* pairs of appendages. Dr. Packard states, " I might say that I have examined hundreds (I believe over a thousand) living eggs, as well as those that had been hardened in spirits, in order to ascertain whether the germ first appears with less than six pairs of legs, but without success " (op. cit., p. 200).

At a little later stage Dr. Packard says (p. 165) "there are six well-marked *cephalothoracic* [cephalic, H. W.] segments; the nine *abdominal* [thoracico-abdominal, H. W.] rings have appeared, no more being added during after life."

These facts appear to me to dispose entirely of the attempts to homologise the larva of *Limulus* with the free-swimming Nauplius of the Copepoda on the one hand, or with the young of the Trilobita on the other.

The number of paired appendages concealed beneath the double shield of the infant *Agnostus, Sao,* or *Trinucleus,* we are entirely unable to discover, it cannot there-

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[1] Mr. C. D. Walcott's researches on the appendages of the Trilobites are not yet completed.

[2] 'Quart. Journ. Geol. Soc.,' 1871, vol. xxviii, p. 59.

fore be more than a supposition that there is any very close connection between a young Trilobite, such as those represented on Pl. XXXII, and a Limulus, such as we have pictured to us by Dr. Packard (Pl. XXXIII, figs. 1—5), possessed of a head-shield affording evidence of at least *six* (if not of seven segments), and a hinder body (representing according to my view the thoracico-abdominal series) composed of nine segments from its third or fourth moult within the protodermal egg-covering even before the absorption of the yolk takes place.

2nd. As to the position of the eyes, Dr. Packard observed "the compound eyes as two white dots on the third segment of the *cephalothorax* (cephalon, H. W.).

"The ocelli (he states) appear still later on in the *mandibulary*[1] or first segment. It is thus proved that the eyes are not in Limulus developed on distinct segments" (op. cit., p. 165). To this I would reply that at this stage most probably, as in some other Entomostraca, the compound eyes are really concealed *beneath* the head-shield. The ocelli, he states, are on the *first* segment; but this is *not* "the mandibular segment" (see pp. 4 and 5 of this Monograph, where, according to Bell, Dana, Bate, and Huxley, the ophthalmic segment is the first, the antennary 2nd and 3rd, and the mandibular the 4th).. But of far higher importance in deciding this point is the position of the nerves in connection with the supraœsophageal ganglion, as shown by Professor Owen, whose plates I am permitted to reproduce (see Pl. XXXIV—XXXVI).

Professor Owen remarks "The first pair of nerves is the 'ocellar' (Pl. XXXVI, *a, a* 1); the second pair of nerves is the 'ocular' (ib., *n* A)." Surely if the *supposed* want of two pairs of antennal nerves taking their rise from the front of the supraœsophageal ring was sufficient to induce Dr. Dohrn to wish to remove the *Limuli* from the Crustacean class, the position of the optic nerve ought to have some weight in deciding the segment to which the eyes must really be referred.

3rd. I believe I have almost in every case (save the one pointed out by Dr. Packard in Part I, p. 39) spoken of the post-oral plate as the *metastoma,* not as the *labium.* Dr. Packard in comparing the *Merostomata* with the *Trilobita* (op. cit., p. 190)—a comparison which I cannot consider as a happy one[2]—speaks of the *metastoma* of *Eurypterus* and *Limulus* as the *hypostoma,* and compares it with the *hypostoma* of the Trilobites with which it clearly has nothing in common; since the hypostome of the Trilobite is always in front of the mouth as in *Apus,* attached to the frontal doublure of the head-shield; whereas the great cordiform lip-plate or "metastoma' of *Pterygotus,* and the 'chilaria' (Owen) of *Limulus* are placed invariably *behind* the circumoral appendages, closing effectually the posterior part of the buccal orifice.

4th. There being, according to Dr. Packard's view, no distinct optic segment in *Limulus,* &c., he treats the first segment as antennal.

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[1] Possibly this may be a misprint, as elsewhere he speaks of it as the antennary segment.

[2] The reader's attention is drawn to the characters of PTERYGOTUS and TRILOBITA given at pp. 226-7.

He further assumes that there are but five segments in the head of the Eurypterida, each bearing a pair of appendages (and also two pairs of eyes, compound and simple), but this head he regards as a cephalothorax comparable with that of *Limulus*, "the thoracic segments being *potential*, but with one segment less, that bearing the first pair of maxillipeds." Dr. Packard further argues that the head in *Limulus* contains organs which in the Malacostraca are lodged in the thoracic region. To this we would reply that in the Decapoda-Brachyura the carapace, which is formed (not by the thoracic somites beneath it, but) by the coalescence of the anterior cephalic somites (antennal and mandibular rings, Spence Bate), encloses precisely similar organs to those found within the head-shield of *Limulus*, and moreover acts as a roof to the branchial chamber; the branchiæ in the Crabs being attached to the thoracic feet as in the King-crabs, although the feet themselves are so differently modified in the latter.

5th. Dr. Packard has not understood Professor Huxley's explanation that "the ovigerous segment" is considered by him as the last cephalic (or the first thoracic, coalesced with the cephalon), and deriving its nerves from thence as shown by Professor Owen (see ante, p. 196); hence arises a part of the difficulty which he finds in agreeing with me as to the number of segments in *Limulus* and *Pterygotus*. The rest is occasioned by attempting to show that the thoracic somites always remain undeveloped in *Limulus* and *Pterygotus*, and that the head is really the cephalothorax, and the hinder body is the abdomen, with an excessive number of segments as in *Branchipus*. At the risk of seeming tedious we therefore venture once more to summarise our views of the Merostomata.

EURYPTERIDA.		XIPHOSURA.
I. CEPHALON:—Bearing the		I. CEPHALON:—Bearing the
1. Ocelli and compound Eyes on the dorsal surface.		1. Ocelli and compound Eyes on the dorsal surface.
2. First antennæ	1 pair aborted.[1]	2. First antennæ.
3. Second antennæ		3. Second antennæ.
4. Mandibles.		4. Mandibles.
5. First maxillæ.		5. First maxillæ.
6. Second maxillæ.		6. Second maxillæ.
7. Maxillipeds.		7. Maxillipeds.

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[1] Prof. Huxley has suggested that the chelate organs in front of the head in *Pterygotus* represent the antennæ, and that the antennules are aborted. If this holds good the remaining organs will be found to correspond exactly in number with *Limulus*. In *Pterygotus* the basal joint of these first chelæ are non-mandibulate, in *Eurypterus*, *Slimonia*, and *Stylonurus* the first pair are simple palpi, but are mandibulate at their base; this would lead one to conclude that they probably represent the antennules in the first and the antennæ in the last-named species.

(Eurypterida.)	(Xiphosura.)
II. Thorax:—Bearing the	II. Thorax:—Bearing the
[1.[1]] Opercular plate having the ovarian openings on its inner surface.	[1.[1]] Opercular plate having the ovarian openings on its inner surface.
2. Branchiæ.	2. Branchial feet.
3. (Ditto ?.)	3. Ditto.
4. No appendages.	4. Ditto.
5. Ditto.	5. Ditto.
6. Ditto.	6. Ditto.
7. Ditto.	7. No appendages.
III. Abdomen (well developed).	III. Abdomen (rudimentary).
No appendages.	No appendages.
1—7. Including the telson.	1, 2. Segments and telson.[2]

The eminent American carcinologist, Professor Dana, writing on *Limulus*, says, "The body consists of three segments, and they may be compared to the segments in *Caligus*. The anterior segment bears six pairs of members; the first appears to correspond to the second pair of antennæ (or third normal segment), the 2nd, 3rd, 4th, 5th, and 6th to the mandibles and the four following pairs of members (or the fourth to the eighth normal segment inclusive).

"The second segment of the body, which we consider as a continuation of the cephalothorax, and not abdominal, bears six pairs of foliaceous organs, analogous to the foliaceous appendages of the posterior part of the thorax in certain *Caligidæ*, in some of which one or two pairs of legs are combined into a hard, thin plate like an apron. These six pairs make up exactly the normal number of cephalothoracic segments, namely, *fourteen*. The abdomen, according to this view, is confined to the last or third segment," *i. e.* the great telson and any portion of the hind-body, the segments of which, though not seen in the adult, are indicated by distinct sutures in the young (see Pl. XXXIII, fig. 12, A and t).

In this sense I shall be happy to adopt the term cephalothorax, but not as applied by Dr. Packard to the head-shield alone.

6th. As to the suggestion that my division between the thorax and abdomen in the Eurypterida "is a purely imaginary one," I will only refer those interested in the subject to the figures of *Stylonurus* (p. 131, fig. 39, dorsal view), in which, as in many other cases, the ornamentation ceases at the end of the thoracic series; to the figure of *Eurypterus* (p. 132, fig. 40), and to the still more striking figure of *Hemiaspis* (p. 177, fig. 64).

7th and lastly. In the method adopted by me in counting the segments I have been actuated by the principle long since suggested by Oken, that, even where a segment is

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[1] Both Professors Huxley and Owen have demonstrated that the nerves supplying this opercular plate arise from the cephalic shield.

[2] Prof. Owen has shown that the 'telson' most probably represents the undeveloped posterior abdominal somites as evidenced by the plexus of nerves it encloses within its hard triangular sheath.

not clearly indicated in any annulose animal, the presence of a pair of appendages always marks the existence of a separate segment.

It is not beyond possibility that a second pair of antennæ may yet be discovered in the genus *Slimonia,* in which their presence has been suspected; but in such a case as that of the supposed suppression of one pair of these organs there is warranty for the theory to be derived from other living Crustacea[1] besides that afforded by a comparison with *Limulus.*

Neither the space allotted me, nor the time at my command, permit me to reply at greater length to Dr. Packard's valuable remarks. To answer them as fully as I could wish would involve an additional part to this Monograph.

I have endeavoured to the best of my ability to interpret aright the fossil remains of the ancient order of the MEROSTOMATA, and I must leave the *onus probandi* to those who object to that interpretation.

Whilst tendering my sincere thanks to Professor Owen for the valuable assistance I have derived from his memoir on the American King-crab, I would venture to touch on one or two points in which I beg leave to dissent from his conclusions.

1st. "No observer," says Professor Owen, "has yet testified to their capacity of uplifting the body from the ground, whether dry or submerged, and of bearing it along by successive steps, as do the jointed legs of the Isopod, the Lobster, or the Crab" (p. 495).

To this I would reply that many years since I carefully observed the living *Limuli* in the Fish-house at the Zoological Gardens, Regents Park, and I have there seen *Limulus* trot briskly along upon the floor of the tank, keeping the edge of its cephalic shield raised clear above the level of the sand.

In the spawning season the female laden with eggs not only *walks* to shore, but carries on her back the salacious male holding on firmly to her carapace by his specially modified antenna. "When left exposed by the tide they hasten (says Dr. Lockwood) to overtake it."

2nd. "In *Pterygotus,* the antennæ," writes Professor Owen, "are forcipated members for the prehension of food, as in *Limulus.* The three succeeding pairs of limbs are still less capacitated, through their smaller size and slenderness, for gradatorial movement of the body. They are adapted to rout out of the sand or mud disturbed by the spade-shaped head the objects of food which the front pair is modified to seize. The larger terminal pair of limbs are more decidedly natatory in form than the corresponding lamelligerous pair in *Limulus.*"

We infer from the spatulate form of the great pair of swimming-feet and the rounded and elongated body that *Pterygotus* was a fairly active swimmer, and that it did not burrow. In fact, the position of the compound eyes upon the *edge* of the head precludes the idea of its front border being used as a shovel like that of *Limulus.*

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[1] The females of *Brachyscelus* are destitute of the inferior pair of antennæ; the male possesses them like other Amphipoda. Spence Bate and Fritz Müller find no trace of them in the young.

The MEROSTOMATA present a reiteration of the same well-marked characteristics observable in the PODOPHTHALMIA and EDRIOPHTHALMIA, namely, the division into 'brachyuran' and 'macrouran' forms, which exemplify well the crawling and swimming types of Crustacea, by the soldering together of the body-segments for strength and compactness in the one, and the retention of free movement of the somites in the other.

Besides being used as organs of prehension, it is highly probable that the several species of *Pterygoti*, all of which were furnished with chelate antennæ, were males, and that their office may have related to sexual functions. *Slimonia*, which attains to a very considerable size, has only minute and simple antennæ destitute of chelæ. This is also the case apparently in both *Eurypterus* and *Stylonurus*. These were perhaps the females.

3rd. Professor Owen observes: "*Pterygotus* and *Eurypterus* resemble *Limulus* in the organs of vision, save that the facets of the large lateral compound eyes are less distinct or less conspicuous in the fossil." In answer to this we would refer to Pls. XIII and XIX (and woodcut, p. 56) of this Monograph, and to the descriptions of many specimens with the facetted surfaces of the eyes *well* preserved. Such admirable specimens were not, however, known to the earlier observers.

We close these notes on modern Limulus with an extract from the admirable Memoir of Professor Alphonse Milne-Edwards, already referred to:[1]—

ON THE GEOGRAPHICAL DISTRIBUTION OF LIMULUS AT THE PRESENT DAY, AND ITS FOSSIL PREDECESSORS.

Two species of *Limulus* are found living at the present day, namely, *L. moluccanus* and *L. polyphemus*. "One of these, *Limulus polyphemus*, is confined to the north part of the Atlantic Ocean; it is found upon the Mexican Coast in the Antilles, and upon the East Coast of the United States, especially Florida and Carolina; but it is not known elsewhere, and in the adjacent regions it entirely disappears. *Limulus* reappears very far from these parts, namely, in the islands of Molucca and in the seas of China and Japan, where it presents peculiarities which specifically distinguish it from the Mexican *Limulus*, but in reality there is only a very slight difference between them, and it seems to me difficult to admit that they were not derived from one primitive stock. In fact, nature never seems to repeat itself in creation, and it is hardly probable that the organic type from which the *Limulus* of the Jurassic Period was derived, the existing *Limulus* of the Atlantic Ocean, and that of the Pacific, have no existing ties of kindred between them and are the result of three distinct zoological creations. But at present the Isthmus of Panama, the continents of America, the Arctic Sea, and the Cold Southern Ocean render all communications between the *Limuli* of the Atlantic and Asiatic regions impossible. It remains therefore to be explained how the descendants of *Limulus polyphemus* have migrated as far as the seas of Japan and Molucca, where we now find *Limulus longispina* or *Limulus moluccanus;* or how the descendants of either of these last-named species have found their way into the Gulf of Mexico, or reached the eastern coast of the United States, and there constituted a locally derived race-species known under the name of *Limulus polyphemus.*

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[1] "Études Anatomiques sur les Limules: Mission Scientifique au Mexique." Paris: 1873, fol. cinquième partie, p. 4.

"One is led to think that the separation between these local races, permanent varieties, secondary species (it matters not here which we designate them) must have taken place at a time before the continents of the new world had acquired their present configuration, and when the warm waters of the Atlantic mixed with those of the Pacific without passing through the Polar Regions or Southern Ocean. Such intercommunication has not, however, existed since the elevation of the Tertiary Strata, which now occupy the depths of the Gulf of Darien, and which extend on the south-east as far as the Banks of New Granada in the Pacific Ocean. The conclusion is that the common ancestors of the American and Asiatic *Limulus* must have been connected *before the Tertiary Period;* and if we find a great hiatus between these animals and those of the Jurassic Period, the remains of which are preserved in the Lithographic stone of Solenhofen, it is because the marine deposits of the Cretaceous Period now accessible to our investigations contain only deep-sea forms of life; whereas the King-crabs are never found save in the neighbourhood of the coast. It seems probable to me that all the *Limuli* of the present epoch are descendants of the *Limulus* of the Jurassic Period, and that they constitute the derivative or secondary species in place of the primordial form; in fact, that they are multiple creations from one single zoological type."

Sub-order—XIPHOSURA, Gronovan. 1764.

Genus 1.—NEOLIMULUS, *H. Woodward,* 1868.

Gen. Char.—Head-shield more than twice as broad as deep, glabellal portion occupying more than half the entire breadth of the head, genal portion small; 'facial suture' crossing the cheeks obliquely from the postero-lateral angle of the shield to the compound eyes. Larval ocelli two (or four?) in number. Post-cephalic segments free, 8 (perhaps 9 or more) in number, central axis rapidly diminishing from before backwards; telson not known.

Species 1.—NEOLIMULUS FALCATUS:—H. Woodw., 1868. Pl. XXXI, fig. 8; and woodcut, fig. 78, p. 234.

NEOLIMULUS FALCATUS, *H. Woodw.,* 1868. Geol. Mag., vol. v, p. 1, pl. i, fig. 1.

It was with extreme interest that I obtained from Mr. Robert Slimon in September

1867, the first evidence of the existence of a true Limuloid form of Crustacean from the uppermost Silurian shale of Lanarkshire.

It is hardly possible to estimate too highly the persevering labours of Mr. Robert Slimon and his sons in the investigation of these Lesmahagow deposits, and one is led to reflect what an enormous amount of additional knowledge would result if other local geologists devoted themselves with the same energy to the investigation of the rocks of their own particular district.

Unlike the majority of the Crustacea obtained from these deposits, our present acquisition cannot be classed among the giants of those days, the specimen only measuring five and a half lines in greatest length, and six lines in greatest breadth. It is preserved upon the extreme edge of a piece of shale, so that, unfortunately, the ultimate segment, as I conceive, and the telson or tail-spine are wanting through being cut off by a cleavage-plane. I have allowed the artist to indicate their probable size in dotted lines in the subjoined woodcut (fig. 78), the rest of the figure actually preserved being given in outline.

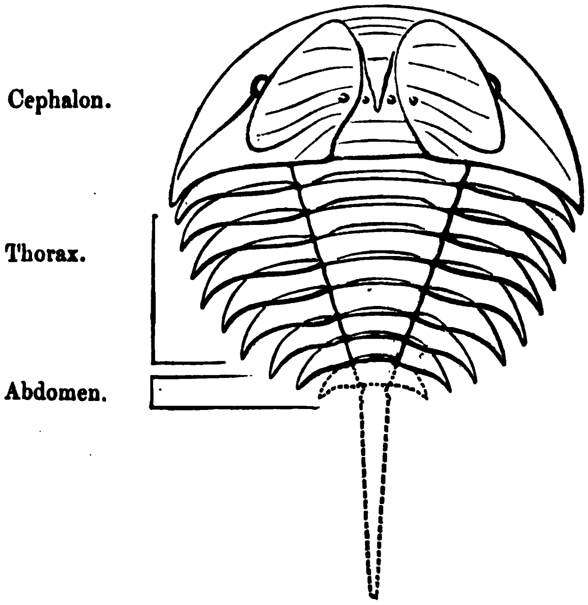

FIG. 78.—*Neolimulus falcatus*, H. Woodw. Upper Silurian, Lesmahagow, Lanarkshire. (Enlarged four times.) Breadth of original six lines; length 5½ lines.

The head-shield is nearly two thirds broader than long, the front margin is semicircular and smooth, and the latero-posterior angles are acute and directed backwards. The posterior border of the head is concave, curving slightly inwards near the centre, and backwards towards the latero-posterior angles.

The glabella is semicircular, and has a tolerably well-defined lateral border separating it from the cheek, but it approaches to and unites with the border of the head-shield in front. A line (which may correspond with the facial suture in Trilobites) passes from the latero-posterior horns of the head-shield, obliquely across the cheeks, and unites with the lateral border of the glabella just where the compound eyes are faintly indicated. A raised V-shaped lobe, having its apex directed backwards, marks the centre of the glabella; near its apex four minute dots are visible under the microscope; these are most probably the larval eye-spots or ocelli. From the sides of this V-shaped lobe two corresponding lines diverge and unite with the posterior border, whilst the lateral ridges marking the semicircular border of the glabella curve inwards on approaching the posterior border of the head-shield and unite with the median lines near the ocelli. The segments succeeding the head-shield are free, and are strongly trilobed, the ends of the pleuræ are all distinct and falcate. The first six segments are reckoned as thoracic; the abdomen probably consisted of three segments, followed by an ensiform telson, but only two of these segments are preserved. The breadth of the segments diminishes rapidly backwards, the first thoracic measuring five lines across, whilst the sixth is only three lines, but the depth of each segment is nearly uniform. The form which appears to possess the same number of segments is the genus *Hemiaspis* from the Lower Ludlow of Leintwardine, in which we find six thoracic and three abdominal segments; but with this exception our Lanarkshire fossil is a much more Limuloid form than *Hemiaspis*, reminding one strongly of Mr. Baily's *Bellinurus reginæ* from the Irish Coal-measures; from this latter, however, it is also easily separable, both in its general form and also in the non-anchylosed condition of the abdomen. From the genus *Prestwichia* it is also separated by the free condition of *all* its segments.

Not being able to refer the Lanarkshire specimen to any previously described genus of Xiphosura, I propose to name it *Neolimulus falcatus*.[1]

If any one fossil *Limulus* gave promise more than any other to aid the palæontologist in connecting the XIPHOSURA with the TRILOBITA ancestrally, it would seem to be the one before us. Its great geological antiquity, as compared even with the *Limuli* of the Coal-measures, naturally leads one to anticipate the discovery of some points indicative of a more generalised type of structure than those of later date. The facial suture in the head-shield, however, seems to be the only approach to a more Trilobitic character than other *Limuli* present.

Of the caudal termination of the body we know nothing, nor are we aware of the form or number of the appendages. Its general facies is certainly Limuloid, not Trilobitic. Nevertheless, the greater freedom of the thoracico-abdominal segments seems clearly to mark it as a more active and natatory type than its adult modern representative, and rather to recall the free-swimming young of *Limulus polyphemus* as it emerges from the egg. (See Pl. XXXIII, fig. 12.)

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[1] *νέος*, young, in allusion to its size, and also its early appearance in time (and *limulus*); and *falcatus*, from the sickle-like form of the body-segments.

The Fossil Limuli of the Coal-measures.

Much of the materials here noticed was placed in my hands many years since for examination at that time[1] by Professor Prestwich, F.R.S.; The Broseley Institute; John Anstice, Esq., of Madeley Wood, Wellington, Salop; Mr. E. J. Hollier, of Dudley; Mr. C. Ketley, of Smethwick, near Birmingham; Mr. J. Farie, of Glasgow; Mr. Thomas Birtwell, of Gawthorpe Gardens, Padiham, Lancashire, and by other friends.

After a careful study of the specimens before me in 1866, I ventured to propose their division into two well-marked genera :[2]

(*a*) Those having movable thoracic segments and anchylosed abdominal ones, to be included in the genus *Bellinurus.*

(*b*) Those in which the thoracic and abdominal segments are not divided and in which the former appear to be anchylosed, to be included in the genus *Prestwichia.*

Genus 2.—Bellinurus,[3] *König.* 1820.

Bellinurus, *König*, 1820. Icones Foss. Sect., pl. xviii, fig. 230.
— *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd ser., vol. xi, p. 112.
— *H. Woodw.*, 1867. Quart. Journ. Geol. Soc., vol. xxiii, p. 32.
— *H. Woodw.*, 1872. Geol. Mag., vol. ix, p. 439.
Entomolithus, *Martin*, 1809. Petrificata Derbiensia, Wigan, 4to.
— *Parkinson*, 1811. Organic Remains, &c., vol. iii, p.* 267, pl. xvii, fig. 18.
Limulus, *Buckland*, 1836. Bridgewater Treatise, vol. i, p. 396, and vol. ii, p. 77.
— *Prestwich*, 1840. Geol. Trans., 2nd ser., vol. v.
— *Portlock*, 1843. Report Geol. Londonderry, p. 316.
Bellinurus? *McCoy*, 1855. Pal. Foss. Woodw. Mus.

Gen. Char.—General form suborbicular. Head or cephalic shield semicircular, slightly arched; the central portion (glabella?) prominent and declining towards the circumference, surrounded with a flattened margin, and terminating at its posterior angles in long spines. Thoracic division composed of five free and movable segments which terminate in spines and diminish gradually towards the posterior extremity. Abdomen (or caudal portion) small, with indications of three coalesced somites to which is articulated an elongated spine (*telson*).

Geological horizon.—Upper Old Red Sandstone and Coal-measures.

Geographical distribution.—Kiltorcan, Co. Kilkenny, Ireland; and Coal-measures,

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[1] See 'Quart. Journ. Geol. Soc.,' 1867, vol. xxiii, p. 31.

[2] Op. cit., p. 32.

[3] Etym.—Βελος, a dart; οὐρὰ, a tail.

Queen's Co., Ireland; Coalbrook Dale, Shropshire; Dudley, Staffordshire; near Mansfield, Nottingham: Kilmaurs, Scotland.

The generic term *Bellinurus* was applied by König, in 1820, to a peculiar Crustacean from the Coal-measures, figured and named by him *Bellinurus bellulus*;[1] previous to this Martin[2] gave a figure and short description of this species, which he called *Entomolithus monoculites*? (*lunatus*), including it with *Trilobites* under the same generic term of *Entomolithus*, a name which would therefore, according to the rules of nomenclature, be inadmissible. Parkinson[3] figures a similar fossil from Ironstone found in the Coal-measures of Dudley, which he includes with the *Trilobites*, stating at the same time that it appeared to be identical with that described by Martin. The same species is figured and noticed by Dr. Buckland under the name of *Limulus trilobitoides*,[4] and afterwards by Prof. Prestwich, in his paper on the Geology of Coalbrook Dale, who adopts the same name, giving a figure of this and other species belonging to the genus, from the Ironstone found in the Coal-measures of Coalbrook Dale.[5] Lastly, General Portlock figures a specimen said to be from Carboniferous shale (most probably, however, Coal-measures), Maghera, Co. Derry, which he doubtfully refers to the same species.[6]

Professor Morris, in his 'Catalogue of British Fossils,' ed. 2, 1854, cites all the above authorities, except Parkinson, referring the same species to *Limulus trilobitoides*, Buckland.

In a paper read by Mr. William Hellier Baily, F.L.S., before the Geological Society of Dublin,[7] a description was given of a specimen (the only one then obtained) from Bilboa Colliery, Queen's County, discovered by Mr. G. H. Kinahan, M.R.I.A., of the Geological Survey of Ireland, in *débris* derived from the three-foot bed of shale immediately over the coal No. III of the section, Castlecomer district. The accompanying fossils in the same bed of shale were a few scattered plant-remains and numerous small bivalve *Unio*-like shells (probably *Myacites*), and others of a mytiloid form, which may be referred to *Myalina*. In this paper some remarks were offered on the allied species from Coalbrook Dale, which had been included with it in the genus *Limulus*, and it was proposed by Mr. Baily, from the characteristic differences they presented and their supposed greater affinity with the *Trilobites*, to remove all these Coal-measure Crustacea from that genus, and group them in a new one, under the name of *Steropis*.

Since then, Mr. Baily, having obtained more complete specimens from Bilboa Colliery, was confirmed in his views with regard to the advisability of separating them from

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[1] 'Icones Fossilium Sectiles,' by C. König, 1820, pl. xviii, fig. 230.

[2] 'Petrificata Derbiensia,' 1809, pl. xlv, fig. 4.

[3] 'Organic Remains,' 1811, vol. iii, p. 274, pl. xvii, fig. 18.

[4] 'Bridgewater Treatise,' 1836, p. 396, vol. i, and vol. ii, p. 77, t. xlvi, fig. 3.

[5] 'Trans. Geol. Soc. Lond.,' ser. ii, 1840, vol. v, pl. xli, fig. 8.

[6] 'Report on Geol. of Londonderry and Tyrone,' 1843, p. 316, pl. xxiv, fig. 11.

[7] 'Journ. Geol. Soc. Dublin,' 1858, vol. viii, p. 89.

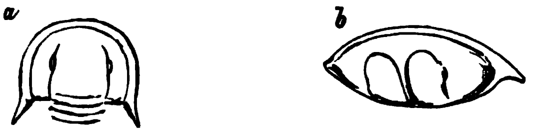
Limulus. Instead, however, of proposing a new generic name, he wisely decided to adopt the appropriate name of *Bellinurus*, which was applied by König to one of the most common species from the West of England.

A very doubtful fossil, from the Lower Silurian, is figured by Professor M'Coy, in Pal. Foss. Woodw. Mus. pl. i E, fig. 22, under the name of "*Bellinurus?*" This may possibly be a phyllopodous head shield.

Species 1.—BELLINURUS KILTORKENSIS:—Baily. MS. (woodcut, fig. 79).

Bellinurus Kiltorkensis, *Baily.* Brit. Assoc., Exeter, 1869, Reports, p. 75.

Fig. 79.



The above sketch and the following note concerning this little form of *Bellinurus* was most obligingly furnished me some time since[1] by my friend Mr. William Hellier Baily, F.L.S., Acting Palæontologist to the Geological Survey of Ireland, but has been overlooked until now.

Fragmentary as is the evidence it affords it is nevertheless of the greatest interest, as assisting to fill up the hiatus between *Neolimulus* in the Upper Silurian and *Bellinurus* in the Coal-measures.

It carries back the genus *Bellinurus* to a much more remote period than its congeners.

The fossil remains of *Bellinurus Kiltorkensis*, Baily, consist of a head somewhat distorted (fig. 79 *b*) and another in much better preservation (fig. 79 *a*) with portions of two body-rings united to it.

It closely resembles *Bellinurus reginæ* from the Kilkenny Coal-measures, especially in being provided with a border and spines developed from the posterior angles, as in many of the Trilobites. (*a.*) Carapace measuring half an inch in breadth and 4½ lines in length; cheek spines about 2 lines long. (*b.*) Carapace distorted.

The eyes are about 2 lines apart, and are placed near the anterior margin of the head, being attached to an arched division forming the central portion of the head.

Two portions of the thoracic rings remain attached to the carapace; they appear to terminate in pointed extremities.

Locality.—From the Upper Old Red Sandstone, Kiltorcan, Co. Kilkenny, Ireland.

The specimens are in the Collection of the Geol. Survey of Ireland, Dublin.

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[1] July, 1872.

Species 2.—BELLINURUS BELLULUS, König, 1820. Pl. XXXI, figs. 3, *a*, *b* (*not* fig. 3, *c*).

Bellinurus bellulus, *König*, 1820. Icones Foss. Sect., pl. xviii, fig. 230.
— — *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd series, vol. xi, p. 112.
— — *H. Woodw.*, 1872. Geol. Mag., vol. xi, p. 439.
Entomolithus (Monoculus) lunatus, *Martin*, 1809. Pet. Derb., pl. xlv, fig. 4.
— — — *Parkinson*, 1811. Org. Rem., vol. iii, pl. xvii, fig. 18.
Limulus trilobitoides, *Buckl.*, 1836. Bridgew. Treat., pl. 46″, fig. 3.
— — *Prestwich*, 1840. Geol. Trans., 2nd ser., vol. v, pl. xli, fig. 8.
— — ? *Portl.*, 1843. Rep. Geol. Londonderry, pl. xxiv, fig. 11.
Bellinurus — *H. Woodw.* Trans. Glasgow Geol. Soc., 1866, vol. ii, pl. iii, fig. 10.

There is little to add to the generic description, already given, of this interesting little King-crab, the first which was discovered in the "pennystone" ironstone nodules of the Coal-measures at Dudley and Coalbrook Dale, Shropshire.

The figures in Martin's 'Petrificata Derbiensia' and in Buckland's 'Bridgewater Treatise' convey the impression that the eyes are situated just *within* the arched front of the glabella, but this is not the fact; their true position is distinctly seen in fig. 3 *a*, namely, on the raised lateral margin of the glabella, nearly midway between the front and back of the head-shield. Fig. 3 *b*, is König's original specimen.

B. bellulus approaches most nearly to Baily's species, *B. reginæ* (compare Pl. XXXI, figs. 1 *b*, and 3 *a*), in the greater relative breadth of the cephalon as compared with its depth, in the prominent thickened doublure of the front border of the head, in the strong doubly arched glabella and the long lateral genal spines of the head-shield.

The thoracic segments have a narrow central axis and are strongly trilobed. Each segment terminates laterally in an acutely pointed and recurved spine. The five thoracic segments appear to have been capable of flexure, the divisions or articuli of the axial as well as the lateral portions of the thoracic somites being distinctly marked.

The series of abdominal somites have their margins marked by sutures, but the axial portion of these segments has coalesced. The axis is marked by a prominent tubercle just anterior to the insertion of the caudal spine, which in this species is not quite so long as the rest of the animal, whereas in *B. reginæ* it is just three times the length of the animal's body.

The spine has a strongly marked ridge running down the centre.

In 1866 I figured and described a small but very perfect specimen of this species from the Coal-measures Kilmaurs, near Glasgow, in the 'Transactions of the Glasgow Geological Society' for that year (vol. ii, pl. iii, fig 10). The total length of this specimen is fifteen lines, of which the head is five lines, the thoracico-abdominal segments four lines, the telson six lines, and the greatest breadth of the head is eleven lines, or more than twice as wide as long.

Localities.—From the Clay-Ironstone of the Coal-measures, Coalbrook Dale; Dudley; Mansfield, near Nottingham; Kilmaurs, Scotland.

Species 3.—BELLINURUS REGINÆ:—Baily, 1853. Pl. XXXI, fig. 1 *a—d.*

BELLINURUS REGINÆ, *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd ser., vol. xi, p. 107, pl. v, figs. 1 A—D.

— — *Baily*, 1863. Quart. Journ. Geol. Soc., 1867, vol. xxiii, pl. i, fig. 1.

Regarding this form Mr. Baily writes:

"In the explanation of Sheet 137 of the Maps of the Geological Survey of Ireland, I have given a short account of the fossils from the Coal-measures of this district, which includes a notice of these remarkable Crustacea from Bilboa. When I visited this locality I was so fortunate as to obtain a very perfect specimen, since named by me *Bellinurus Reginæ* (represented on Pl. XXXI, fig. 1 *a*).

"On another visit a still more perfect specimen (1 *c*) was obtained by the gentleman who accompanied me on that occasion, Mr. John Edge, to whom I am indebted for that and the loan of other specimens, which have materially assisted me in drawing up these descriptions.

"General form broadly ovate, acuminate posteriorly; axis convex. Cephalic shield three and a half times as broad as long, bow-shaped anteriorly, and surrounded by a narrow and flattened margin; the posterior angles produced into long spines, which are directed outwards; central portion, or glabella, smooth and moderately convex, of the same breadth as the axis of the thorax at its junction, but decreasing gradually towards the anterior margin. Eyes central, lunate, attached to these divisions. Thoracic rings (somites) five, the lobes of the first twice as broad as the axis, those of the last rather less in breadth than the axis, the lateral lobes extending in a straight line, each being furrowed and terminating in a spine, the length of which diminishes in regular gradation towards the tail; each of the rings of the axis bears a moderate-sized tubercle. Tail or caudal portion very small, having about three slightly marked divisions on each side, to which is appended or articulated an extremely long spine (*telson*), being three times the length of the other portion of the animal, broad at the base, and tapering gradually to a point.

"The little Crustacean to which I have given the above specific name was found by me in the *débris* of the same coal-pit which yielded the next species; it is in a very perfect condition, and exhibits in a remarkable manner the extravagant development of its various body-segments into long spines spreading out on each side of the body, and gradually decreasing as they approach the tail, from which proceeds an enormous spine. These characters sufficiently distinguish it from any other species. The head and body in the specimen figured appear to have been a little squeezed together. Another specimen of what I believe to be the same species, obtained by Mr. John Edge, is still more perfect, with the exception of the tail-spine, a portion of which has been broken away; it shows a slight wrinkling or furrowing of the expanded margin of the cephalic shield, as well as the sulcated pleuræ and single tubercle upon each ring of the axis terminating in a larger and more obtuse prominence on the tail. The spine or telson which is attached to this portion exhibits a central longitudinal ridge, having a membranous expansion on each side, similar to that noticed by Parkinson as occurring in the species described by Martin, and which I have referred to *B. bellulus*, König.

"The following are the measurements of fig. 1 *a:*

Length from anterior margin of cephalic shield to end of tail	5 lines	or	10 mill.
Length from anterior to posterior margin of cephalic shield .	2½ „	„	5 „
Breadth of cephalic shield	6½ „	„	13 „
Length of body and tail	2½ „	„	5 „
Breadth of body at cephalic shield . . .	4 „	„	8 „

"Measurement of fig. 1 *c:*

Total length from anterior margin of cephalic shield to point of telson	1 inch 1 line	or	27 mill.
Breadth at widest part of spines . .	7 lines	„	15 „
Breadth of cephalic shield . . .	5 „	„	10 „
Length of telson	10 „	„	20 „ "

Locality.—From Coal-shale, Bilboa Colliery, Queen's County.

Species 4.—BELLINURUS ARCUATUS:—Baily, 1863. Pl. XXXI, figs. 2 *a, b.*

BELLINURUS ARCUATUS, *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd series, vol. xi, pl. v, fig. 2 *a—c*.

"General form broadly ovate, acuminate posteriorly; axis convex. Cephalic shield semicircular, slightly elevated, declining towards the circumference, and surrounded by a narrow, flattened margin, the central portion or glabella having three ridges extending to about two thirds the breadth of the shield, rounded at their anterior extremity, and forming a double arch, the central portion being broadest at its posterior extremity, the two outermost ridges curving at about half their length towards the very slightly raised semicircular eyes, and continuing beyond the posterior extremity of the shield in two sharp straight spines, which project over the body about one tenth of an inch; the posterior angles of the cephalic shield are produced into long spines, as in the preceding species, three tenths of an inch in length, slightly curved, and spreading out on either side from the body. Thoracic rings five, which, as in the preceding species, decrease in breadth towards the posterior extremity; the lateral lobes, extending in a straight line, terminate in a short spine, and having an angular furrow, which proceeds to the end, curving at the same angle to the point of each spine. Caudal extremity small, with two or three radiating divisions, to which is appended a spine about equal in length to the head and body.

"This Crustacean differs from the preceding one in having much shorter spiny terminations to the pleuræ and a much shorter tail-spine. The detached head or cephalic shield is more orbicular, and the arched rings proceeding from the middle portion of the head (*glabella*) terminate on each side in short spines, a character not observed in any of the specimens of *B. Reginæ*. I have not succeeded in obtaining good specimens of this species with the body and tail entire; an imperfect one forms the centre of a concretion in the shale, and exhibits a portion of the body with the tail-spine uncompressed, showing distinctly the division of each thoracic ring, with its grooved lateral angles as in the *Trilobites*. In another specimen, which was accidentally relieved from the shale, exposing both sides, the body was found to be doubled back upon the head, like an *Ampyx* or *Trinucleus*. This species is allied to *Bellinurus bellulus*, König, but differs from it in the more orbicular form of the head, the spring termination of the pleuræ, and the greater proportion of the body to the cephalic shield.

" The following are the measurements of fig. 2 :

Total length	1	inch or	25	mill.
Total breadth	11	lines ,,	22	,,
Length of body	7	,, ,,	15	,,
Breadth of cephalic shield	8	,, ,,	17	,,
Length of cephalic shield	4	,, ,,	8	,,
,, telson, about	½	inch ,,	12	,, "

Locality.—Found with the previous species at Bilboa Colliery, Queen's County.

Mr. Baily makes the following observations on the beds in which *Bellinurus* occurs:

" As to the question of the freshwater or marine habitat of these Crustacea and their associated fossils, I am inclined to the opinion that the deposits in which they occur were of freshwater or estuary origin, from the abundance of small shells like *Unio*, and others very similar to the freshwater *Mytilus* (*Dreissena*) *polymorphus*, accompanied by the remains of succulent or marshy plants. This opinion corresponds with the observations of Martin and Prestwich. Other theories have been advanced attributing a general marine origin to the coal-beds, in support of which great stress has been laid upon the fact of the occurrence of minute spiral bodies found attached to some of the plant-remains, and formerly referred to *Spirorbis*, a marine genus of Annelida common upon our shores at the present day, where it is generally attached to sea-weeds, and is well known as *Spirorbis nautiloides*. These little spiral bodies of the Coal-measure plants have, however, been described by Göppert as a fungus under the name of *Gyromyces ammonis*, and are figured by Geinitz in his fine work on the Coal-plants of Saxony. We have here, therefore, an instance of the great caution required in drawing general conclusions from insufficient data, and would rather concur with the remarks offered on the subject at p. 54 of this journal, believing that the Coal-measures afford evidence of having been deposited under both freshwater and marine conditions.

"The discovery of these peculiar Coal-measure Crustacea in Ireland, with associated shells and plants corresponding so remarkably with those found in similar deposits at Coalbrook Dale, in Shropshire, and other parts of the midland counties in England, is a point of great palæontological interest, showing their distribution over a wide area, and indicating the prevalence of the same condition in both counties, although at localities so widely distant."

Species 5.—BELLINURUS KŒNIGIANUS:—H. Woodw., 1872. Pl. XXXI, figs. 3 *c* and 4.

BELLINURUS KÖNIGIANUS, *H. Woodw.* Geol. Mag., 1872, vol. ix, pl. x, fig. 8, p. 439.

This new form was obtained from the Dudley Coal-field, and is quite distinct from the type-species *B. bellulus*, König.

The angles of the carapace are blunt, and not produced into long spines, and the five free thoracic somites terminate in obtuse serrations, not in recurved spines, as in *B. bellulus*. The thorax also is relatively broader in proportion to the head; the axis of the body is strongly arched and nearly straight, and does not diminish gradually towards the posterior extremity, as in the other species, although the pleuræ themselves contract to half their breadth from the first to the fifth segment. The raised circular border of the glabella is not so distinctly defined as in *B. bellulus*, but the central axis is more strongly marked. The eyes are not very well seen, but they occupy the same relative position on the margin of the raised glabella, as in *B. bellulus*.

The abdominal division consists, as in the other species, of three coalesced segments, which are, however, only indicated by three marginal serrations.

The tail-spine (telson) is not preserved, but its articulation with the abdomen is strongly marked.

Greatest length of entire body, 9 lines; greatest breadth of head-shield, 1 inch; length of five free thoracic segments, 3 lines; breadth of first free thoracic segment, 10 lines; breadth of fifth free thoracic segment, 5 lines; breadth of central axis of body-segments, 2½ lines.

I have named this species after Mr. Charles König, the original founder of the genus, and for many years the Keeper of the Geological and Mineralogical Collections in the British Museum. The original specimen is preserved in the British Museum, and was obtained by C. Ketley, Esq.

Locality.—From the Clay Iron-stone of the Coal-measures, Dudley Coal-field.

Genus 3.—Prestwichia, *H. Woodward.* 1867.

Limulus, *Prestwich*, 1840. Trans. Geol. Soc., 2nd ser., vol. v.
Bellinurus, *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd series, vol. xi, p. 113.
Prestwichia, *H. Woodw.*, 1867. Quart. Journ. Geol. Soc., vol. xxiii, p. 32.

"White Hats"

This genus was proposed by me, in November, 1866, to include certain forms, first noticed by Professor Prestwich from the Coal-measures of Coalbrook Dale, found in nodules of clay-ironstone (called "~~pennystone~~"), which have long been known to yield organic remains, such as the cones of *Lepidodendron* (*Lepidostrobi*), the leaves of *Alethopteris*, *Neuropteris*, and *Cyclopteris*, and more rarely the remains of ARACHNIDA (*Etophrynus Prestvicii*), and CRUSTACEA.

Gen. Char.—*Limuli* having a more or less elliptical head-shield, bearing the eyes upon the lateral margins of the glabella; the lateral borders developed into genal spines; the thoracico-abdominal series being apparently united together into one buckler to which the short telson was articulated: central axis of body-segments narrow.

Distribution.—Coal-measures, Airdrie; Padiham, Lancashire; Coalbrook Dale, Shropshire; Dudley; Nottingham.

Species 1.—PRESTWICHIA ANTHRAX, *H. Woodw.* Pl. XXXI, figs. 6 and 6 *a*.

Limulus anthrax, *Prestwich*, 1840. Trans. Geol. Soc., 2nd ser., vol. v, pl. xli, figs. 1—4.
Bellinurus anthrax, *Baily*, 1863. Ann. and Mag. Nat. Hist., 3rd ser., vol. xi, p. 113.
Prestwichia anthrax, *H. Woodw.*, 1867. Quart. Journ. Geol. Soc., vol. xxiii, p. 32, pl. i, fig. 2.

This characteristic species well illustrates the coalescence of the segments of the posterior buckler, which peculiarity I ventured to suggest as a distinguishing mark between the *Bellinuri* and the *Prestwichiæ*. Whilst fully admitting that a knowledge of the complete animal (which, unfortunately, we do not possess), might materially tend to modify our classification of these ancient King-crabs, yet, nevertheless, the palæontologist is glad to seize upon any such salient point of structure which may present itself in these fossil forms; and, though it may appear trivial, we may fairly accept it, under reservation, until better specimens afford a clearer insight into their anatomical details.

This species and the next following (*P. rotundata*) were first figured and noticed (though not described) by Mr. Prestwich in his celebrated "Memoir on the Geology of Coalbrook Dale," published in the 'Transactions of the Geological Society' for 1840. Fragmentary remains have since been obtained from Airdrie, Dudley, and from Mansfield, in the neighbourhood of Nottingham.

It is at once readily distinguished from the other Coal-measure *Limuli* by the more outward direction of the genal spines of the head, giving a curious pointed lateral extension to the shield. The hinder border of the cephalon also curves upwards and outwards, so that the cheek-spines seem to spring from the centre of each side of the head, instead of from the postero-lateral border.

The frontal doublure is strongly marked, as in *Bellinurus reginæ*. The details of the eyes and ocelli cannot be well made out, but from the detached head (Pl. XXXI, fig. 6 *a*), one is led to conclude that the glabellal border was marked by a doubly arched front, as in the *Bellinuri*. The back of the head-shield at its articulation with the axis of the thoracic somites is marked by three prominent spines directed backwards. The thoracico-abdominal somites are coalesced, and form a heart-shaped post-cephalic buckler. The border on either hand is marked by six remarkably long slender recurved spines, those of the thoracic somites being as much as seven lines in length. The telson is seven lines long, but it evidently went *beyond* the circumference of the Clay-ironstone nodule (in which it is embedded) into the shale, and its extremity is therefore lost. The narrow but strongly marked axis of the hinder shield was apparently ornamented by a single row of tubercles down the centre of the somites. Traces of three long slender-jointed limbs are seen projecting from beneath the head-shield in Professor Prestwich's specimen; this is the only indication of limb-appendages which these Coal-measure specimens afford.

The following are the measurements of Professor Prestwich's specimen (Pl. XXXI, fig. 6):

Greatest breadth of head-shield to extremities of genal spines .	2½ inches.
" length of head-shield . . .	9 lines.
" breadth of thorax	1¼ inch.
" length of thorax	11 lines.
" breath of axis of thorax . . .	3 lines.
Length of telson	7 lines.

[Another form of *Limulus* (*Prestwichia Danæ*) from the Coal-measures, of Illinois, U.S., has been described by Messrs. Meek and Worthen,[1] for which Mr. Meek has since proposed the generic name of *Euproops*, in allusion to the anterior position of its eyes.[2]

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[1] 'Geol. Surv. Illinois,' 1866, vol. ii; 'Paleontology,' p. 395, pl. xxxii, fig. 2.

[2] 'Geol. Mag.,' 1867, vol. iv, p. 320.

This new form is considered by Mr. Meek to be nearer *Prestwichia anthrax* than to *Bellinurus* by reason of its anchylosed segments, but he considers that it differs from the former in the comparatively small and quadrangular form of the glabella.

Having compared Mr. Meek's figures of *Euproops Danæ* with Professor Prestwich's type specimen of *P. anthrax*, I am in a position fully to appreciate Mr. Meek's accurate comparison of *Euproops* with that species. It seems hardly possible to do more than separate them specifically. Of their generic identity I think there can be but little doubt.]

Species 2.—PRESTWICHIA ROTUNDATA:—H. Woodw. Pl. XXXI, fig. 5.

LIMULUS ROTUNDUS, *Prestwich*, 1840. Trans. Geol. Soc., 2nd series, vol. v, pl. xli, figs. 5—7.
PRESTWICHIA ROTUNDATA, *H. Woodw.*, 1867. Trans. Glasgow Geol. Soc., vol. ii, p. 240, pl. iii, fig. 8.
— — *H. Woodw.*, 1867. Quart. Journ. Geol. Soc., vol. xxiii, pl. i, fig. 1, p. 32.

The original specimen of this well-marked form of Palæozoic King-crab is represented by both the intaglio and relievo impressions preserved in a nearly circular nodule of ironstone from Coalbrook Dale in the cabinet of Professor Prestwich, F.R.S. The relievo side is figured on our plate (Pl. XXXI, fig. 5).

Professor Milne-Edwards, who, at the request of Mr. Prestwich, examined this interesting Coal-measure Crustacean at the time of its discovery, considered it to be a distinct species, and he specially directed attention to the curious membrane-like border of the thoracico-abdominal segments which connects them together.

Other specimens have since been submitted to me from Dudley by Messrs. Charles Ketley and E. Hollier; and from Kilmaurs, near Glasgow, by Mr. Farie. These specimens add but little to our knowledge of the species, derived from the original type-specimen, save that the Kilmaurs example has exceedingly elongated genal spines, thus greatly altering the "circular outline" which suggested to Mr. Prestwich the trivial name of *rotundus*.

Mr. Baily writes ('Ann. and Mag. Nat. Hist.,' 1863, 3rd ser., vol. xi, p. 107):—"A species, closely allied, if not identical with *Bellinurus* (*Limulus*) *rotundus*, Prestwich, sp., was also obtained at the same locality which had yielded *B. reginæ* and *B. arcuatus* (Bilboa Colliery, Queen's County), but as it is scarcely perfect enough for description I have preferred referring it, with a doubt, to that species."

The head-shield is almost three times as broad as deep; the outline is nearly semicircular. The front margin of the glabella is arched, and just within its anterior border are the larval eye-spots; the compound eyes are placed on its raised lateral border. The glabella is divided down the centre for half its length by a raised ridge, which terminates in a blunt spine posteriorly, whilst in front it bifurcates, forming an arched ridge on either side of the mesial line. Two equidistant ridges, nearly two lines apart, also spring from the posterior border on each side of the mesial ridge of the glabella, and unite with and complete the arched ridges in front. Two lesser arches unite the median and the two next lateral ridges, half way up on either hand. The axis of the thoracic somites is narrow; each somite is ornamented on the median line with a single blunt tubercle, a somewhat larger tubercle marks the coalesced and rudimentary abdominal portion. The broad membranous margin of the thoracico-abdominal somites is divided by seven strongly marked spines of nearly equal length, which do not, however, project far beyond the broad membranous margin. The telson is unknown.

The following are the measurements of Professor Prestwich's specimen (Pl. XXXI, fig. 5):

Greatest breadth of head-shield	2 inches.
„ length of head-shield	9 lines.
Length of genal spines[1]	2 „
Greatest breadth of thoracic somites	1 inch 7 lines.
„ „ axis of thoracic somites	3 lines.
Breadth of thorax at point of union with head-shield	1 inch.
Length from back of head-shield to point of insertion of the telson	9 lines.
From back of head-shield to edge of membranous border of abdomen	1 inch.

Species 3.—PRESTWICHIA BIRTWELLI:—H. Woodw., 1872. Pl. XXXI, figs. 7*a*—*c*.

PRESTWICHIA BIRTWELLI, *H. Woodw.* Geol. Mag., 1872, vol. ix, pl. x, figs. 9 and 10, p. 440.

For a knowledge of this small but well-marked and very characteristic species of Coal *Limulus* I am indebted to the kindness of Mr. Thomas Birtwell, of Gawthorpe Gardens, Padiham, Lancashire, who obtained it from the Coal-measures at the Cornfield Pit on the south bank of the River Calder, near Padiham. It was from this pit that the small fossil Arachnide, *Architarbus subovalis*, H. Woodw.,[2] was obtained by Mr. Birtwell.

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[1] Length of genal spine in specimen from Kilmaurs 7 lines.

[2] See 'Geol. Mag.,' 1872, vol. ix, p. 385, pl. ix, figs. 1 *a*, *b*.

This new species, of which there are two examples, both figured in our Pl. XXXI, figs. 7 *a*, *b*, exhibits the most complete anchylosis and obliteration of the divisions of its body-segments of any of the Coal *Limuli*. The entire body measures 8 lines in length, and 8 in greatest breadth; of this the head-shield measures 4 lines in length, and 8 in breadth; the anterior (thoracic) part of the post-cephalic shield is 6 lines broad, diminishing to 2 lines near the posterior (abdominal) part; length of the thoracico-abdominal somites 4 lines. The telson measured 4 lines in length. The head-shield is very tumid, the posterior genal angles are not produced; the glabella is divided down the centre by a slender ridge; its front border (as in most other species) forms two arches, between which and in front of the head-shield, the larval eye-spots are seen; the small compound eyes are placed midway upon the lateral border of the glabella.

The divisions of the thoracico-abdominal segments are only faintly indicated along the central axis of the body; the margin does not show the usual serrations or spines, as in the other species; but the number of segments appears to have been the same. The coalesced abdominal segments were marked by a very prominent spine or tubercle, the top of which has, however, been broken off.

I have named this species *Prestwichia Birtwelli*, after its discoverer, Mr. Thomas Birtwell, in whose collection the specimens are preserved.

Genus 4.—CYCLUS, *De Koninck*. 1841.

CYCLUS, *De Koninck*, 1841. Descript. Animaux Foss., p. 591.
— *Salter and H. Woodw.*, 1865. Cat. and Chart Foss. Crust., p. 17.
— *H. Woodw.*, 1868. Brit. Assoc. Rep. Norwich, p. 72.
— *H. Woodw.*, 1870. Geol. Mag., vol. vii, p. 554.
AGNOSTUS, *Phillips*, 1836. Geol. Yorkshire, vol. ii, p. 240.

In my fourth Report to the British Association (1868) I described, among other Crustacea, two species belonging to the genus *Cyclus*, one of which still remains unique. Since that date I have, by the kindness of Professor T. Rupert Jones, F.R.S., received a number of specimens of this genus, collected by Professor Harkness, F.R.S., Mr. Joseph Wright, F.G.S., of Belfast, and Mr. J. H. Burrow, of Settle, Yorkshire; from the Carboniferous Limestone, which I described in the 'Geological Magazine' for 1870, p. 554.

Prof. de Koninck, of Liége, the founder of the genus *Cyclus*, has made the following remarks thereon:

"There is no doubt this animal should be ranged with the Crustacea, and in Milne-Edwards's order *Trilobita abnormalia* and *Battoidea*, near to *Agnostus*."

M. de Koninck also considered it probable that the body of *Cyclus* was soft and very contractile, that it was a parasite, and that the two tubercles which we have called eyes really covered those organs; and further, that the ribbed border protected the feet when the animal was in repose.

We must differ from M. de Koninck in referring this form to the Trilobita. If truly an adult, it must be placed near *Apus* with the other shield-bearing Phyllopoda. If a larval form, it may have been the early stage of *Prestwichia* or some other of the Coal-measure *Limulidæ*. Nor do we think it in the least probable that the shield of *Cyclus radialis* was flexible or contractile, its original segments being completely soldered together into one piece.

If we except *Cyclus Rankini* (Pl. XXXII, fig. 42), which may have been chitinous in its substance like the modern *Limulus*, the other species seem to have had a firm calcareous covering like the test of *Phillipsia* and *Brachymetopus*, found associated with them in the same beds of Carboniferous Limestone in Yorkshire, Ireland, and Belgium.

Species 1.—CYCLUS BILOBATUS:—H. Woodw., 1870. Pl. XXXII, fig. 45 *a*, *b*.

CYCLUS BILOBATUS, *H. Woodw.*, 1870. Geol. Mag., vol. vii, p. 554, pl. xxiii, figs. 3, 3 *a*.
— — *H. Woodw.*, 1873. Brit. Assoc., 7th Report on Fossil Crustacea, p. 304.

This specimen is from Settle, in Yorkshire, and was collected by Mr. J. H. Burrow. Its greatest length is 3 lines. Viewed in profile it is nearly hemispherical (see fig. 45 *b*), its greatest elevation being 1½ line. In general form it reminds us strongly of the dorsal aspect of certain Coleopterous Insects of the genus *Coccinella* or *Cassida*, the elytra being represented by the two large smooth posterior lobes of the shield, with their dividing ridge, and the head and thorax by the anterior third. The border is not flattened and curved outwards in this species, as in *C. radialis* and some others, but is bent downwards and terminates abruptly at the same angle as the rest of the carapace (see fig. 45 *b*). The frontal margin was probably divided into six parts, but it is only imperfectly preserved.

The anterior part of the carapace or buckler is divided transversely from the posterior and larger portion by what, for convenience, we may call "the cervical furrow," whilst a median or "dorsal furrow," divides it down the centre for about one fourth of its entire length, thus separating the anterior parts into two equal lobes; here the median furrow diverges right and left in a crescent-shaped curve, and unites with the cervical furrow, leaving a small elevated median area (cardiac region?), which contracts rapidly backwards and is then prolonged as a narrow dorsal ridge—dividing the two elytra-like lobes, to the posterior border. The anterior and expanded end of this dorsal ridge is ornamented on either side, at its union with the cervical furrow, by two small crescent-shaped lobes.

The surface of the carapace is everywhere smooth and devoid alike of tubercles and puncta.

Species 2.—CYCLUS TOROSUS :—H. Woodw., 1870. Woodcut, fig. 80, *a*, *b*.

Cyclus torosus, *H. Woodw.*, 1870. Geol. Mag., vol. vii, p. 555, pl. xxiii, figs, 4 and 4 *a*.

— — *H. Woodw.*, 1873. Brit. Assoc. Reports, 7th Report on Fossil Crustacea, p. 304.

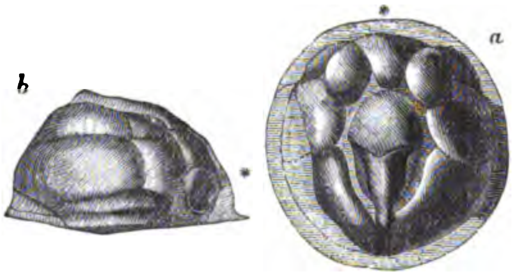

Fig. 80.—*Cyclus torosus*, H. Woodw.
a, dorsal aspect; *b*, profile; * indicates the anterior border of shield.

The buckler in this species is nearly circular, and is 4 lines in diameter. Its dorsal line (viewed in profile) is very tumid, and is elevated 2 lines above its border (see fig. 80, *b*). The cervical furrow divides the carapace transversely into two nearly equal parts (in this respect offering a marked contrast to *C. bilobatus*); the anterior moiety is divided into eight lobes, and the posterior into three. A narrow, slightly flattened border appears to have nearly, if not quite, surrounded the shield.[1]

In front of the carapace is a median, somewhat triangular lobe, having its rounded apex directed backwards; this is flanked on either side by two nearly round lobes, two placed subcentrally and two near each latero-anterior border. Uniting these five anterior lobes with the cervical furrow are two lateral five-angled lobes and a central seven angled (cardiac ?) lobe or area. Behind the cervical furrow a dorsal ridge, of marked elevation, divides the posterior half of the carapace into two rounded lobes, which nearly unite behind—being only separated by a narrow dorsal ridge—but are widely separated in front, not only by the interposition of the dorsal ridge—which expands like the head of a pillar before reaching the cervical furrow—but also by the intercalation of two narrow lobes or ridges on either side of the expanded dorsal ridge. The even contour of the carapace is only markedly interrupted by a greater degree of prominence in the dorsal ridge just where it expands. The lobes are all roundly tumid, and, like the preceding species, almost smooth. *Cyclus torosus* was obtained from the Carboniferous Limestone of Little Island, Cork, by Mr. Joseph Wright, F.G.S.

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[1] Several of these forms may have been destitute of a rim in front (see *Halicyne*, Pl. XXXII, figs. 48 and 49).

Species 3.—CYCLUS WRIGHTII:—H. Woodw., 1870. Pl. XXXII, fig. 47 *a*, *b*.

Cyclus Wrightii, *H. Woodw.*, 1870. Geol. Mag., vol. vii, p. 555, pl. xxiii, figs. 5 and 5 *a*.

— — *H. Woodw.*, 1873. Brit. Assoc. Report, 7th Report on Fossil Crustacea, p. 304.

This well-preserved form (which we have named in honour of the discoverer, Mr. Joseph Wright, F.G.S., of Belfast, who has devoted much time and attention to the investigation of the fossils of the Carboniferous Limestone of Ireland) was procured from the Limestone of Little Island, Cork.[1] It is oval in form, being $2\frac{3}{4}$ lines in length, 2 lines in breadth, and 2 lines in height. *Cyclus Wrightii*, like *C. bilobatus*, has a mimetic resemblance to a Coleopterous Insect, but the disproportion between the anterior and posterior divisions of the carapace is even greater than in *C. bilobatus*, the anterior part forming one fifth of the entire length. A narrow, flattened border encircles four fifths of the carapace, the anterior fifth apparently terminating abruptly at the margin without any border. The dorsal ridge is prominent and broad, and extends from the anterior to the posterior border, commencing as a narrow ridge behind. It spreads out into two successive rounded expansions, and again contracts somewhat before reaching the cervical furrow, in front of which it again becomes much wider, then contracting slowly towards the front. A somewhat triangular lobe flanks each side of this dorsal line in front, whilst two nearly round lobes are placed, one on either side of it, behind the cervical furrow. Nearer the latero-anterior margin two other rounded lobes are formed, one on either side, by a branch of the cervical furrow.

The two great latero-posterior lobes of the buckler have a single corrugated ridge, commencing very faintly at the posterior dorsal line, and running forward and curving around the sides of the carapace, and becoming more strongly marked near the cervical furrow.

The surface is smooth or slightly and very finely granulated.

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[1] Another specimen, obtained by Professor Harkness, F.R.S., from the Carboniferous Limestone of Keisley, near Appleby, Westmoreland, appears to be referable to this species, but the intractable nature of the matrix renders it impossible for me to work it out satisfactorily (see Prof. Harkness's paper, 'Quart. Journ. Geol. Soc.,' 1865, vol. xxi, p. 243, &c.).

Species 4.—CYCLUS HARKNESSI:—H. Woodw., 1870. Pl. XXXII, fig. 44 *a, b.*

Cyclus Harknessi, *H. Woodw.*, 1870. Geol. Mag., vol. vii, p. 556, woodcut; and pl. xxiii, figs. 6 and 6 *a*.
— — *H. Woodw.*, 1873. Brit. Assoc. Report, p. 304.

This elegant form approaches most nearly to *C. radialis*, but the border of the shield appears to be wanting. Its length is 3½ lines, breadth 3 lines, elevation 2 lines. Another specimen measured 5 lines in length, 3½ lines in breadth, and 3 lines in height.

In this species the usual cervical furrow, dividing the anterior from the posterior portion, is indicated by a ridge which commences in the middle of the shield where the raised dorsal line, instead of terminating, diverges into two lateral branches directed obliquely forwards, froming a Y-shaped elevation, from the branches of which the cervical furrow is continued down to the latero-anterior border.

From the margin of the dorsal ridge seven ribs take their rise on either side, and descend the steep border of the buckler towards its rim, where, it is probable, they terminate in rounded extremities as in *Cyclus radialis* (Pl. XXXII, fig. 43 *b*), but the matrix conceals it (see fig. 44 *b*). I have since been so fortunate as to detach a minute portion of matrix from one of the specimens, and have satisfied myself that such is really the case, so that to fig. 44 *b* a margin needs to be added along the basal line, as in the accompanying woodcut (fig. 81). The ribs are interrupted near the crown of the shield by two furrows, which encircle the posterior three-fourths of the buckler, so as to break up the ribs near the summit into two sets of tubercles, the inner and upper series being the larger and the lower series the smaller; the surface of the ribs is finely granulated. In front, and partly enclosed by the Y-shaped cervical ridge, and forming the top of the anterior portion of the buckler, are four rounded lobes, with polygonal borders arranged in a diamond-shaped pattern, the posterior one (cardiac?) being the largest of the four.

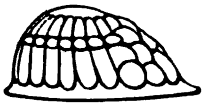

Fig. 81.—Restored profile of *Cyclus Harknessi*, H. Woodw.

Placed around and forming a double border to these four lobes are eleven (?) others arranged, firstly, five in one row, and secondly (along the outer margin), six. The surface of the buckler is finely granulated.

The three specimens found belonging to this species, which I have dedicated to my friend Prof. Harkness, F.R.S., are all from the Carboniferous Limestone of Little Island, Cork, from the collection of Mr. Joseph Wright, of Belfast.

Species 5.—CYCLUS RADIALIS:—Phillips, sp., 1836. Pl. XXXII, fig. 43 *a*, *b*.

Agnostus radialis, *Phillips*, 1836. Geol. Yorks., vol. ii, t. xxii, fig. 25.
Cyclus — *H. Woodw. and Salter*, 1865. Cat. and Chart Foss. Crust., p. 17, fig. 14.
— — *H. Woodw.*, 1868. Brit. Assoc. Report, p. 75, pl. ii, fig. 1.
— — *H. Woodw.*, 1870. Geol. Mag., vol. vii, pl. xxiii, figs. 2 and 2 *a*, p. 557.

I was at first doubtful whether the *Cyclus radialis* of M. de Koninck, from Belgium, really represented the *Agnostus radialis* (?) of Phillips, from the Carboniferous Limestone of Bolland, Yorkshire. I have fortunately been able to see and examine the original specimen of *Cyclus radialis* of M. de Koninck (and Gilbertson's specimens from Bolland, Yorkshire, preserved in the British Museum), and find that it does agree with the figure in Philips's 'Geology of Yorkshire' (vol. ii, t. xxii, fig. 25), but it entirely disagrees with M. de Koninck's *magnified* figure. I have therefore redrawn the Belgian form (see 'Brit. Assoc. Rept.,' 1868, pl. ii, fig. 1). Mr. Hollick in drawing *Cyclus radialis* for the 'Geol. Mag.,' 1870, vol. iii, was good enough to point out that the posterior border of one of M. de Koninck's specimens, from the Carboniferous Limestone of Visé, Belgium, drawn on our Plate XXXII, fig. 43 *a*, *b*, was not broken (as I had supposed and figured it in my Report, op. cit., pl. ii), but was naturally indented upon the posterior border on each side, so as to leave a rudimentary spine at the termination of the dorsal ridge, as seen in our present figure.

Cyclus radialis (fig. 43) is an elegant shield-shaped carapace, 5 lines long by 4 lines in breadth; its general form is hemispherical, with a narrow smooth border (roundly indented behind, so as to leave a rudimentary medial spine in the centre); the shield is divided down its centre by a raised longitudinal (dorsal) ridge, from which radiate seven diverging ribs (transversely wrinkled), whose rounded extremities reach the lateral and posterior border.

The anterior cephalic portion occupies about a quarter of the entire shield, and is ornamented by the spreading out of the raised central ridge, and by two subcentral, rounded prominences, which correspond in position to eyes, but are not facetted. The ribs are ornamented, each with from three to five tubercles irregularly disposed over their surface.

This species (which is the first that was published of this genus) occurs in the Carboniferous Limestone of Little Island, Cork, Bolland and Settle in Yorkshire, and Visé, Belgium.

Species 6.—CYCLUS JONESIANUS:—H. Woodw., 1870. Pl. XXXII, fig. 46 *a*, *b*.

Cyclus Jonesianus, *H. Woodw.*, 1870. Geol. Mag., p. 558, vol. vii, woodcut, figs. 1 and 2.
— — *H. Woodw.*, 1873. Brit. Assoc. Report, p. 304.

Whilst engaged in drawing up this paper Mr. Joseph Wright kindly sent me several additional specimens from Ireland, and amongst them one which is evidently a new form.

The specimen, which measures 3 lines in length, 2½ in breadth, and 2 lines in height, was obtained from the Carboniferous Limestone of Little Island, Cork.

The carapace, which is finely granular all over, is divided in front of the cervical furrow into eight lobes, and behind the same furrow into two lobes, which latter occupy more than half the shield. The two posterior lobes are divided down the mesial line by the dorsal ridge, which at rather more than one third the length stops short. Here two minute depressions occur, and the cervical furrow may be said to branch out right and left, inclosing a central triangular space (cardiac region?), having its base-line directed forward and slightly crenated. In front of this triangular lobe two oblong lobes, united along the median line, occupy about one fourth the length of the carapace (gastric region?), and are bordered by two pairs of lateral and one central, somewhat triangular lobe in front, the whole being probably surrounded by a narrow upturned rim or border.

Cyclus Jonesianus rivals *C. Wrightii* in height, to which form and to *C. bilobatus* it is no doubt closely related.

I have great pleasure in dedicating this species to my kind friend and fellow-labourer in palæontology, Professor T. Rupert Jones, F.R.S., of the Royal Military and Staff Colleges, Sandhurst, to whom I am indebted for much valuable assistance in understanding the hosts of the Bivalved Crustaceans (the *Ostracoda* and *Phyllopoda*), to the fossil forms of which he has devoted so many years of patient, ardent, and successful research.

Species 7.—CYCLUS RANKINI:—H. Woodw., 1868. Pl. XXXII, fig. 42.

Cyclus Rankini, *H. Woodw.*, 1868. Brit. Assoc. Report, p. 72, pl. ii, fig. 2.
— — *H. Woodw.*, 1870. Geol. Mag., vol. vii, pl. xxiii, fig. 1, p. 558.

I first drew attention to this remarkable form at the Meeting of the British Association at Norwich, in 1868.

This new form of *Cyclus*, discovered by Dr. Rankin, of Carluke, in the Carboniferous Shales of that place, is most remarkable in appearance, and far more like a parasitical or larval form of Crustacean than is the *Cyclus radialis*, which certainly possessed a hard calcareous test. A comparison of the two, however, leaves no doubt in my mind in referring them both to the same genus.

The shield is about 4 lines in diameter, and conveys the idea of an extremely thin test, flattened out on the soft shale by pressure. The "eye-spots" occupy the same relative position as in *C. radialis;* but the divisions which represent the costæ are six, not seven, in number in this species, and these anastomose together on the lateral border, and diverge, not from a raised median ridge, but from a broad, V-shaped central area (cardiac region?). One is reminded by this Crustacean of the appearance of *Argulus*, *Bopyrus*, and other recent parasitic forms, and also of the disk-shaped *Discinocaris*, from which, however, it differs in the "eye-spots" and costated shield.

For this new species I propose the name of *Cyclus Rankini*, after its discoverer.

[HALICYNE, von Meyer, 1847.

Hermann von Meyer has figured in the 'Palæontographica,' 1847, vol. i, p. 134, a small Crustacean head-shield under the name of *Halicyne agnota*, and a second species under the name *H. laxa*, from the Muschelkalk of Rottweill in Germany. Goldfuss originally figured it as *Olenus serotinus;* afterwards Münster referred it to *Limulus* ('Beitrage,' 1841, Bd. i, t. v, f. 1).

To both these conclusions von Meyer demurs; to *Limulus* because no eyes are visible, and to the *Trilobita* because none are found in rocks younger than the Carboniferous formation.

The form of this head-shield is extremely like that of *Agnostus;* but the *Agnostidæ* are confined to the Lower Silurian strata, between which and the Trias are the long intervening series of the Upper Silurian, the Devonian, Carboniferous, and Permian formations. At the date of my report (1868) I was inclined to place *Halicyne* with *Bunodes*, *Hemiaspis*, &c., among the aberrant forms of the *Limulidæ*, being under the impression that it was only a part of a Crustacean, probably a head-shield. Having now the advantage of a large series of Carboniferous *Cycli* with which to compare it, I feel no longer any doubt about placing it with *Cyclus*, that being the older name.]

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XXXIV. Anatomy of „ „
XXXV. „ „ „
XXXVI. „ „ „

PLATE I.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1. An almost entire body of *Pterygotus anglicus*, Agassiz, the original specimen measuring 23 inches in length, preserved on a slab of grey micaceous sandstone from Turin Hill range, Forfarshire. Two thirds natural size. See page 34.

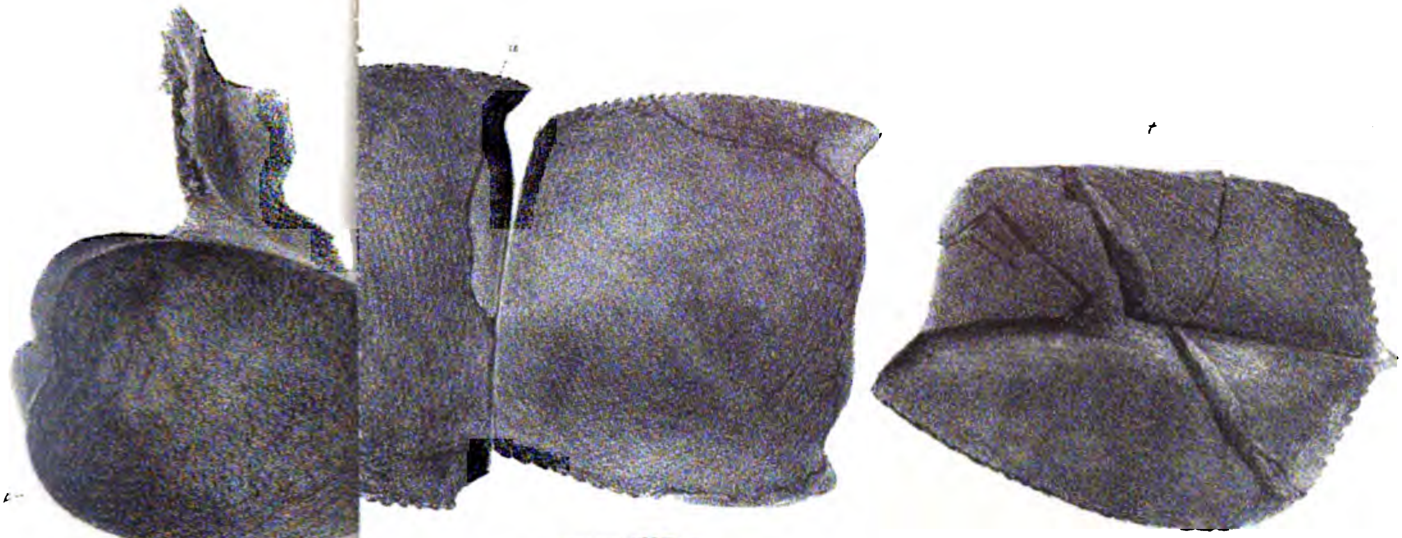
2. A detached head of *Pterygotus anglicus*, Ag., figured of the natural size, showing the marginal eyes (*e*, *e*). See page 36. From the Old Red Sandstone, Forfarshire.

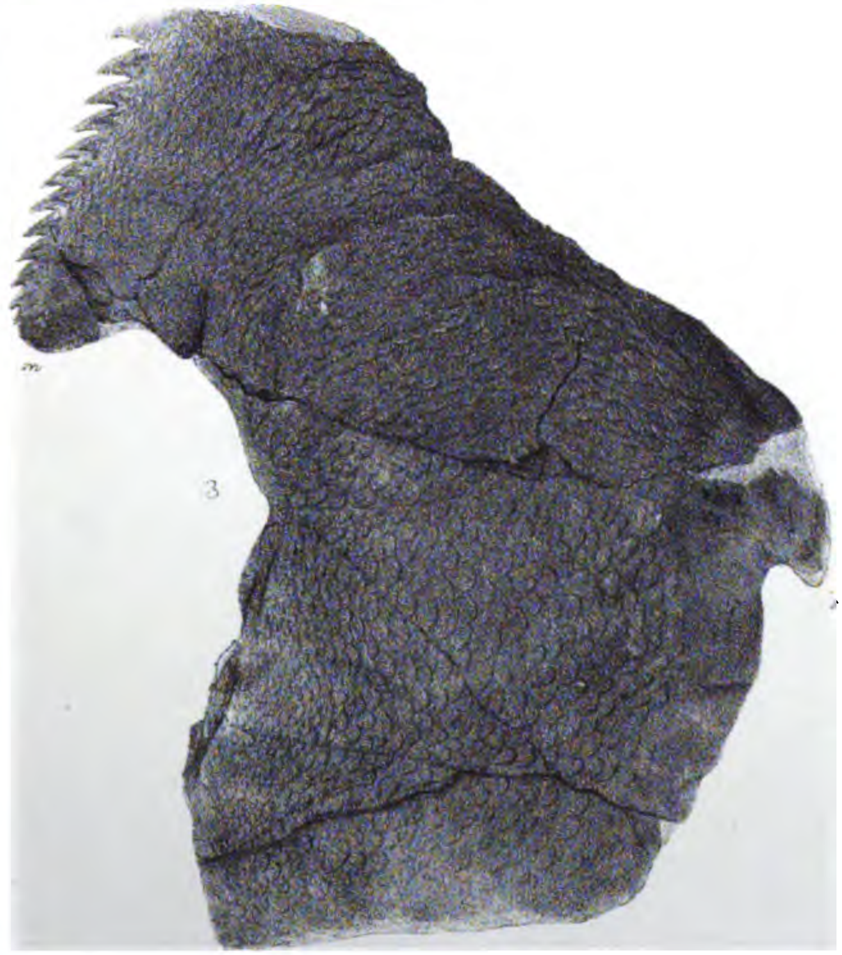
2*a*. A small portion of the surface of the head, enlarged.

3. Basal joint of the left maxilliped of *Pterygotus anglicus*, Ag. (natural size), from the Old Red Sandstone, Forfarshire. See page 38.

4. *Pterygotus minor*, H. Woodw. (natural size), from the indurated shale overlying the "Arbroath Paving-stone," Farnell, Forfarshire. See page 35.

The above specimens are all from the Museum of James Powrie, Esq., F.G.S., Reswallie, Forfar.





F. Waller imp

OTUS MINOR, *H Woodw.*

PLATE II.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

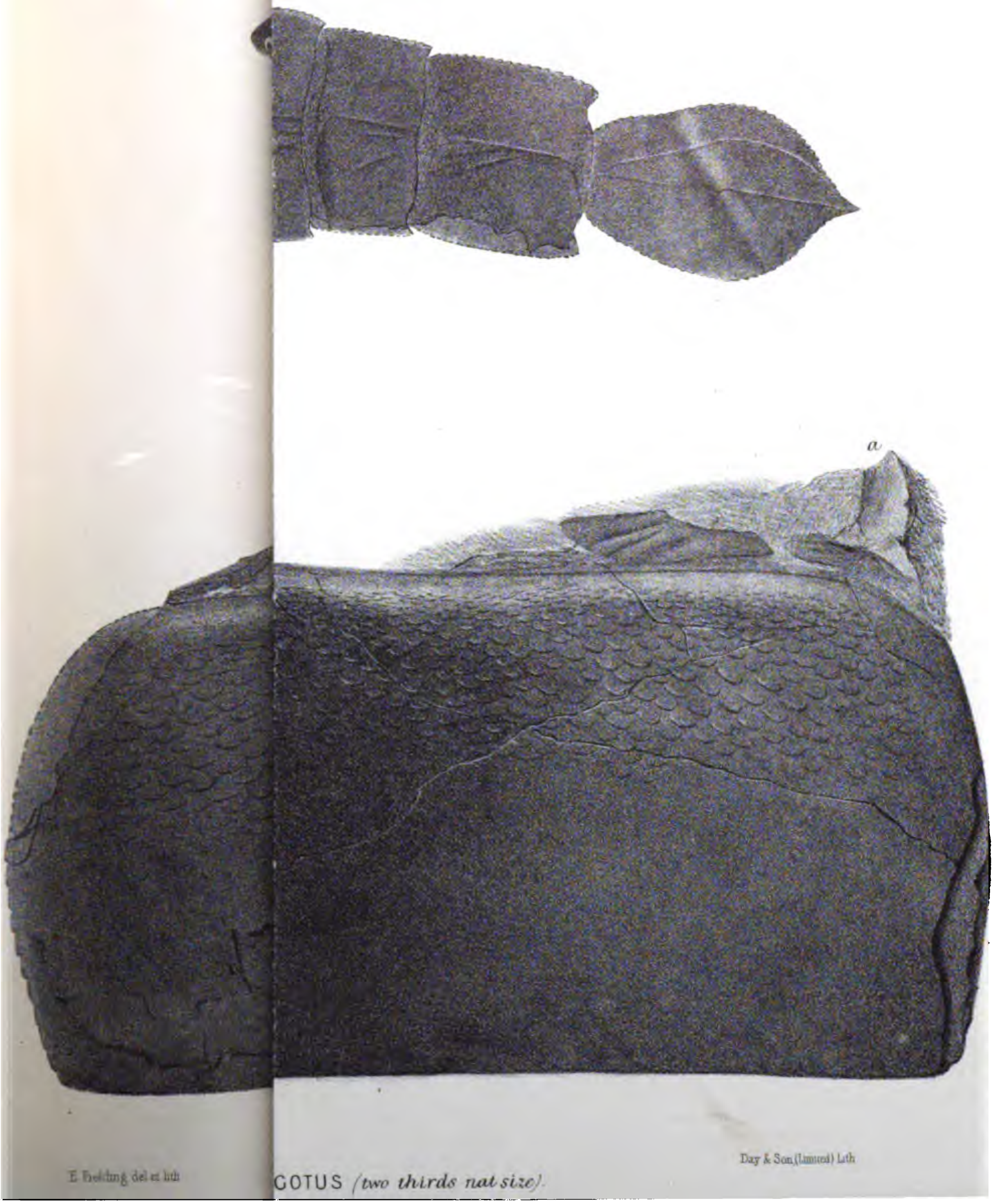
1. *Pterygotus anglicus*, Ag. (natural size), from the indurated shale overlying the "Arbroath Paving-stone," Turin Hill range, near Forfar. One of the most entire specimens obtained. See page 34.

   The dorsal surface is exposed to view; but the organs of the mouth, &c., are seen impressed through the integument of the head-shield.

   From the Museum of James Powrie, Esq., F.G.S., Reswallie, Forfar.

2. *Pterygotus anglicus*, Agassiz. Probably about the third, or fourth body-segment of a very large individual, the original measuring 18 inches in breadth and 4¼ in depth. From the Devonian of Forfarshire. See page 41.

   The original specimen is preserved in the British Museum.



E. Fielding del et lith

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GOTUS *(two thirds nat size).*

PLATE III.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

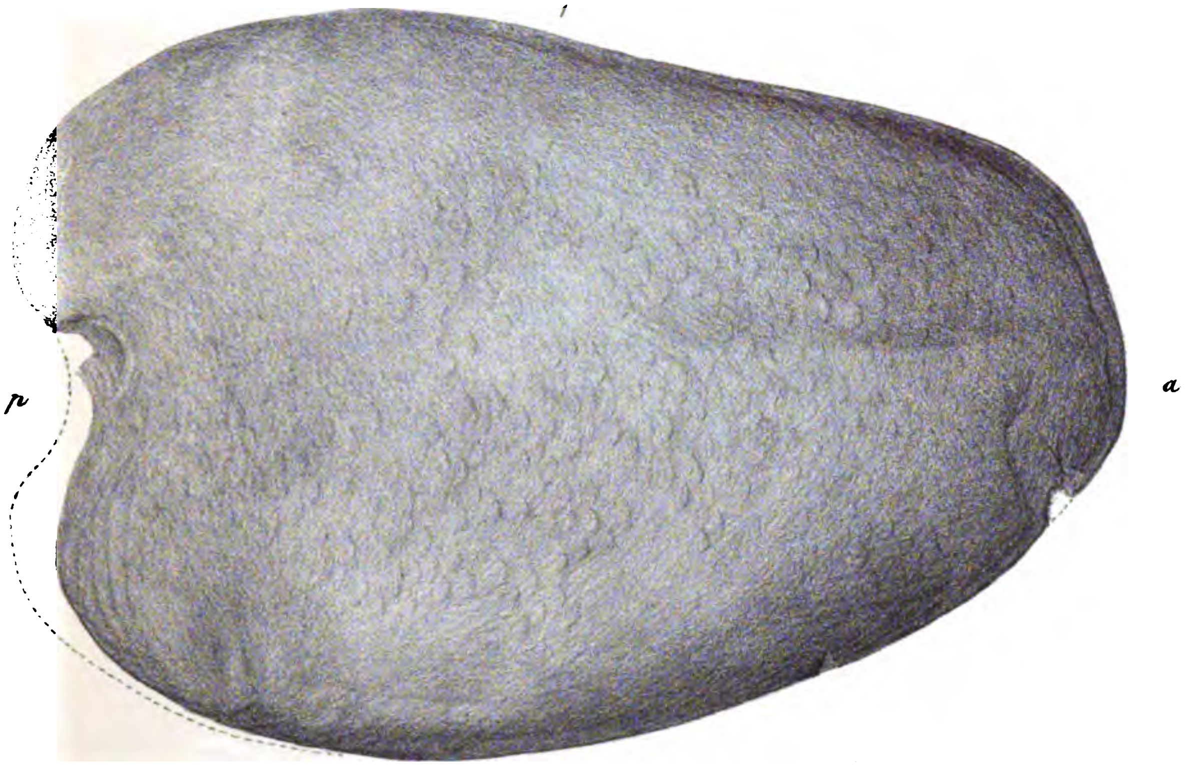
1. A metastoma or post-oral plate of *Pterygotus anglicus*, Ag., figured of the natural size, from the Devonian of Forfarshire. See page 39.

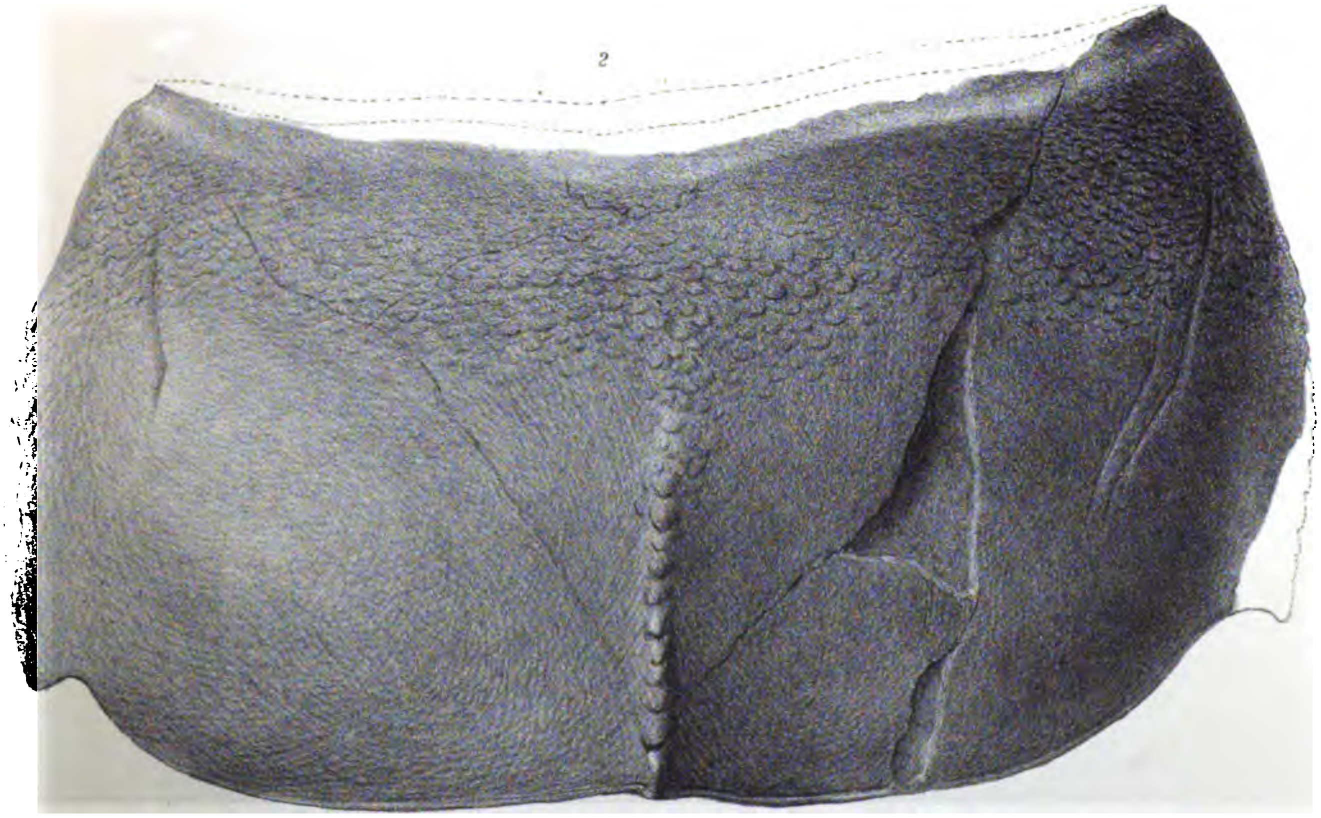
2. Antepenultimate body-segment (corresponding in position to the segment marked *a* in fig. 1, Plate I); the upper surface is here represented of the natural size.

From the Devonian of Forfarshire. See page 42.

The original specimens are preserved in the British Museum.

DEVONIAN CRUSTACEA





F. Fielding del^t et lith
M & N Hanhart imp

PTERYGOTUS ANGLICUS, *Agassiz (nat. size)*

Fig 1. Post-oral plate ... Fig 2. Ante-penultimate body segment.

PLATE IV.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

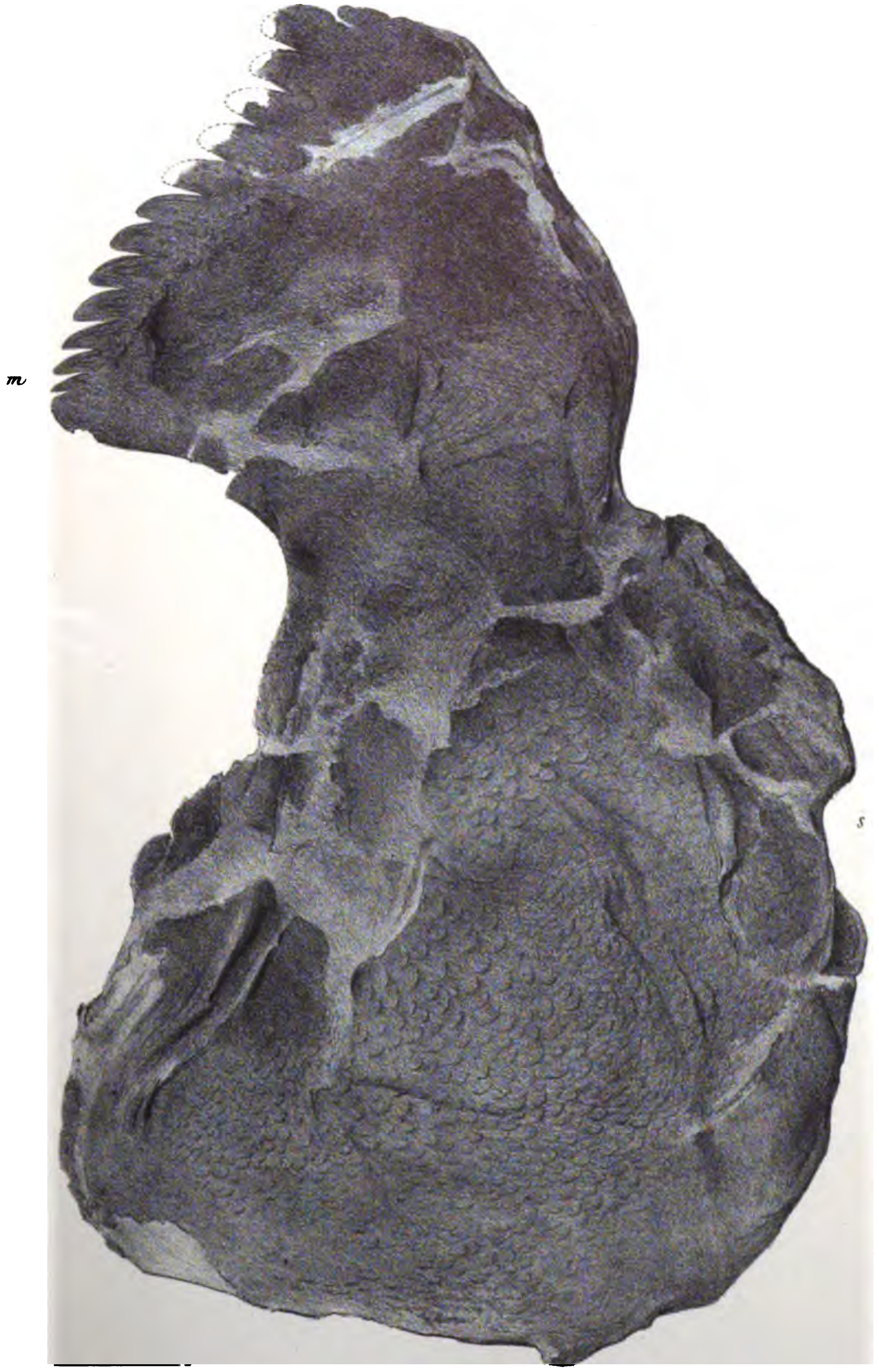
Sub-Order—EURYPTERIDA.

Basal joint of a left maxilliped (or *ectognath*) of ***Pterygotus anglicus***, Agassiz, figured of the natural size, from the Devonian of Forfarshire. See page 38.

m, the toothed mandibular border; *s*, the point of articulation for the proximal end of the swimming-foot. (See Plate VIII, fig. 1, 6.)

The original specimen is preserved in the British Museum.

DEVONIAN CRUSTACEA.



F. Fielding del et lith
M & N Hanhart imp

BASAL JOINT OF A SWIMMING FOOT (*nat. size*) PTERYGOTUS ANGLICUS. *Agassiz*

FORFARSHIRE.

PLATE V.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1—4 Represent the detached penultimate joint of the swimming-foot or maxillipede (*prognathite*, Huxley) of *Pterygotus anglicus*, Agassiz, from the Devonian of Forfarshire. Figured of the natural size. (See pages 38 and 39.)

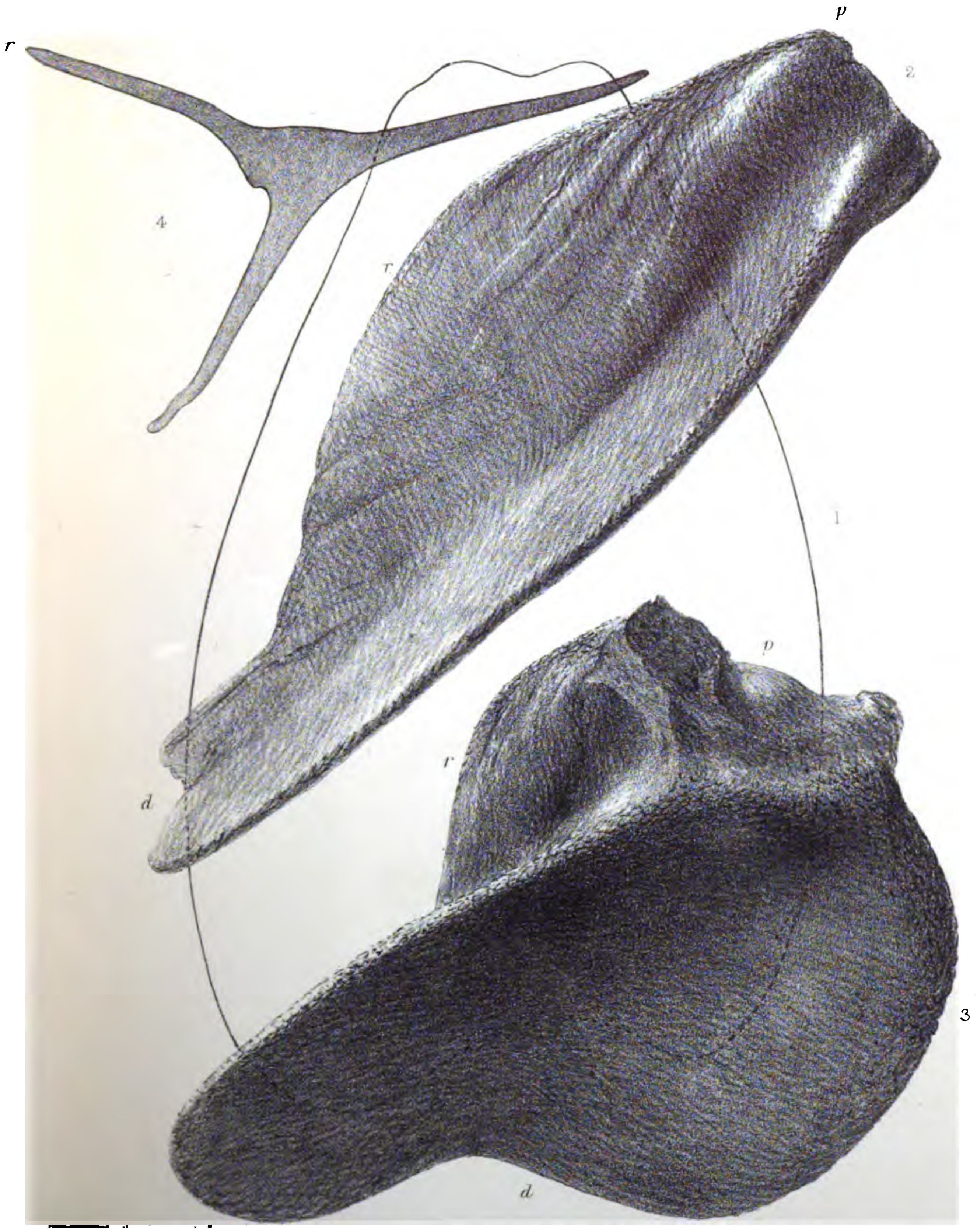
1 Represents the outline of the joint as seen from the under surface. (See Plate VIII, fig. 1, 6.)

2. Side view of same, exhibiting the upper surface and the ridge (*r*); *p*, proximal articular surface; *d*, distal extremity, to which the oval terminal palette was articulated.

3. View (foreshortened) of joint as seen from the proximal end (*p*), showing the under side and the ridge (*r*) upon the dorsal surface, somewhat bent over to one side.

4. Section (drawn from careful measurement) of about the centre of the joint, showing the thickness of the internal portion. (*r* represents the ridge, as in figs. 2 and 3.)

From the Museum of James Powrie, Esq., F.G.S., of Reswallie, Forfarshire.



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Day & Son Limited Lith

PTERYGOTUS ANGLICUS *Agassiz (Nat. Size*

PLATE VI.

DEVONIAN CRUSTACEA.

Order—Merostomata.

Sub-Order—Eurypterida.

The largest telson or terminal joint which has yet been discovered of ***Pterygotus anglicus***, Agassiz. From the Old Red Sandstone near Forfar. Figured of the natural size. See page 42.

The distal border of the penultimate joint, to which it was attached, is indicated in outline.

From the Collection of James Powrie, Esq., F.G.S., Reswallie, Forfar.

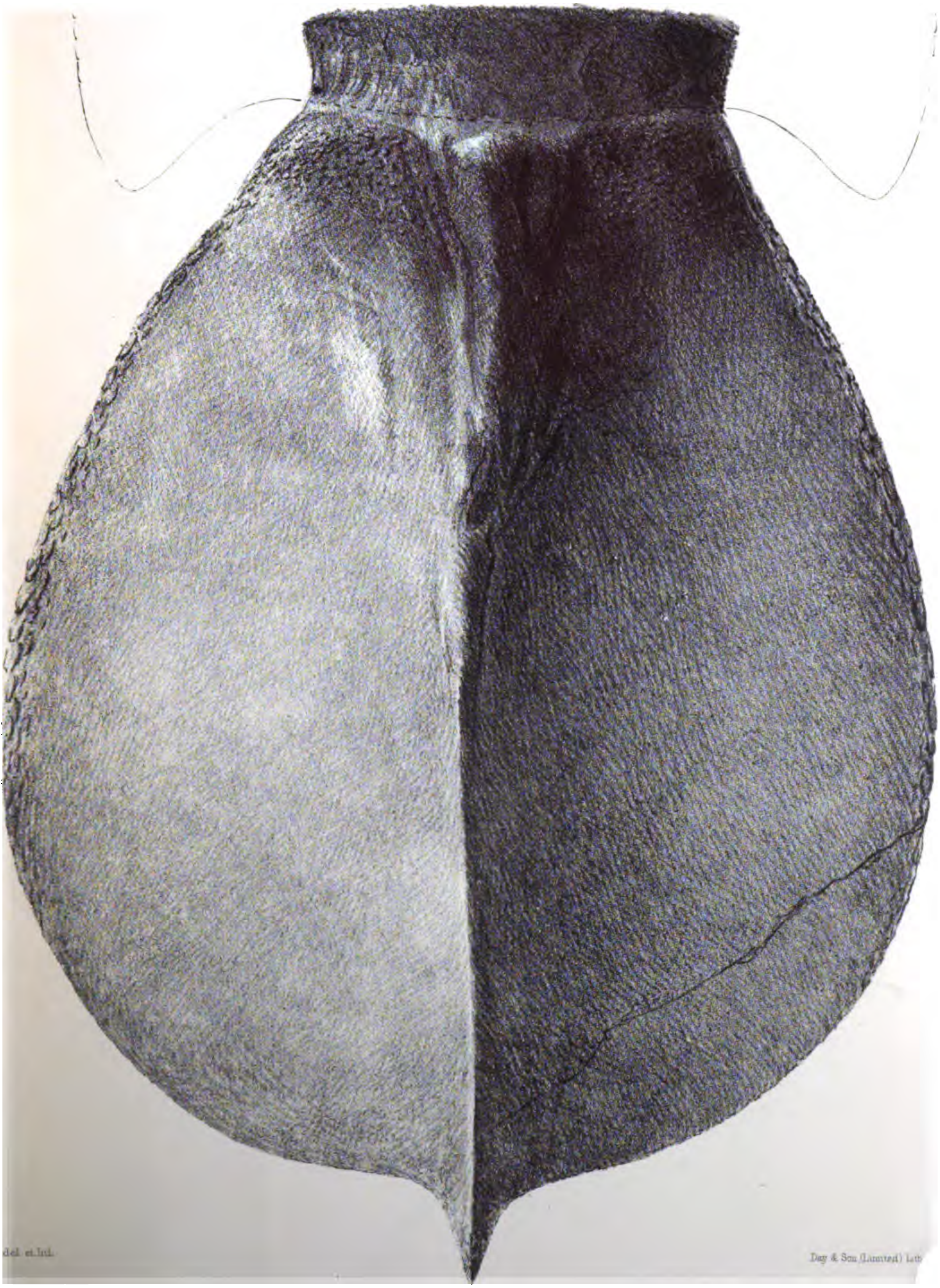

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PLATE VII.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Appendages of *Pterygotus anglicus*, Agassiz. Copied (with the exception of fig. 4) from Plates VI and VII of Messrs. Huxley and Salter's Monograph, from the admirable drawings of Mr. C. R. Bone.

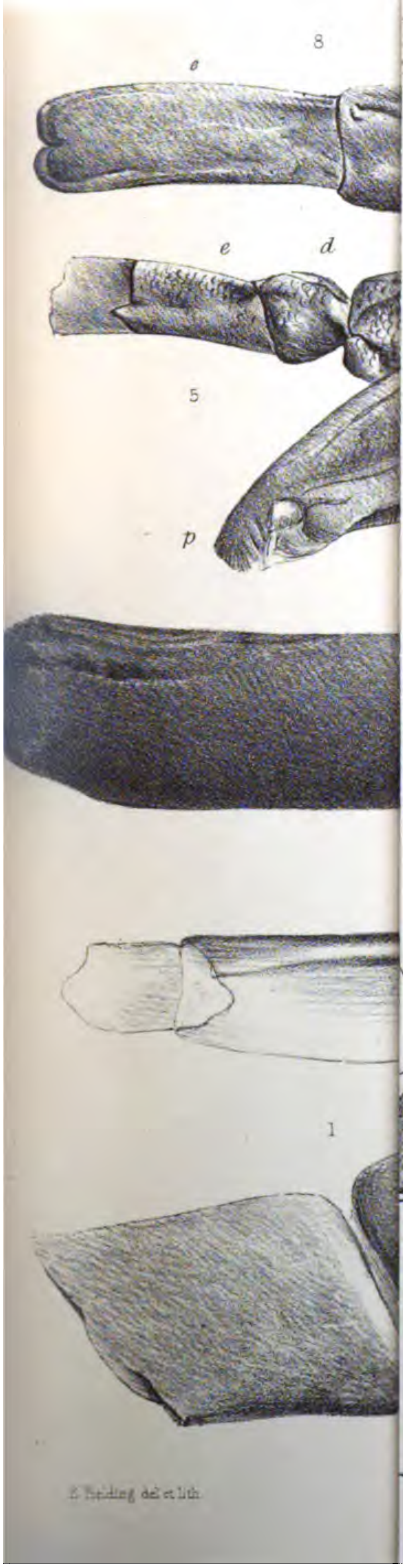
FIG.

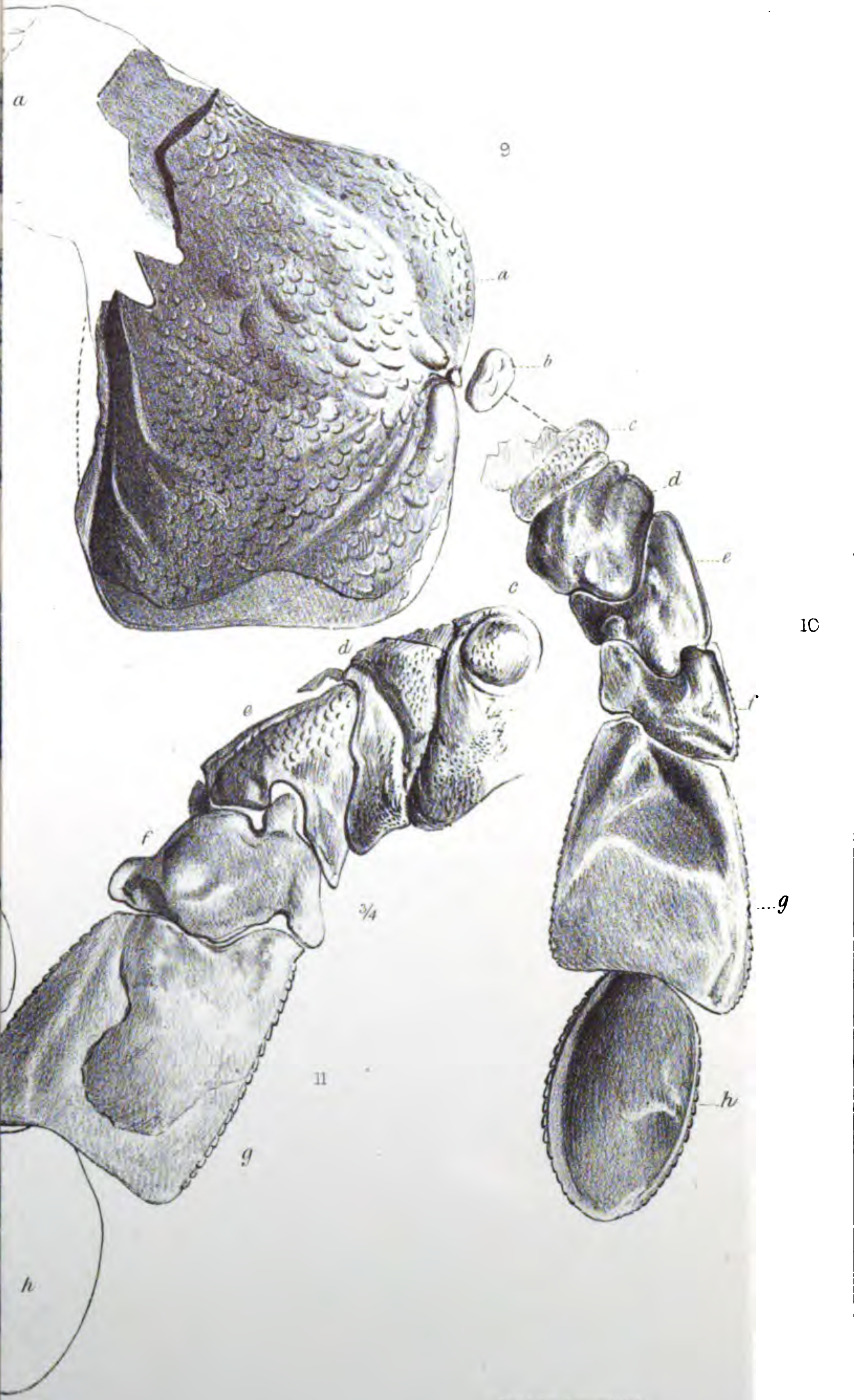
1. One of the chelate antenna, the largest known. From Forfarshire. Page 37.
   From Lady Kinnaird's Museum, Rossie Priory, Perthshire.
2. Another specimen, smaller than fig. 1, but having three of the articulations preserved, p. 37.
3. Chelate termination of an antenna, having the extremities of the chelæ preserved, p. 37.
   From the Watt Institution, Dundee.
4. Antepenultimate joint of antenna, natural size. From Forfarshire, p. 37.
   In the British Museum.
5. One of the mandibles or maxillæ (endognath, Huxley), with the first three joints of its palpus, p. 37.
   From the Watt Institution, Dundee.
6. Another similar appendage from the opposite side of the head, with four joints of the palpus preserved.
   From the Museum of Lady Kinnaird, p. 37.
7. A detached mandible or maxilla, differing somewhat in form from figs. 5 and 6, p. 27.
   From the Watt Institution, Dundee.
8. The second and third joints of a large palpus, p. 37.
   From Lady Kinnaird's Museum.

9 & 10. A maxilliped (ectognath, or swimming-foot), having the several articulations nearly all united to the broad basal joint, which has, however, been broken off at its serrated border, and is restored in outline at *a*, p. 38.
From the Museum of Lady Kinnaird.

11. Part of a very large swimming-foot reduced to three fourths its natural size. The letters refer to the corresponding joints in fig. 10, p. 38.
    From the Museum of Lady Kinnaird.

All these specimens are of the natural size except fig. 11.





E. Fielding del. et lith.

Day & Son (Limited) Lith.

PLATE VIII.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA, *Dana*.

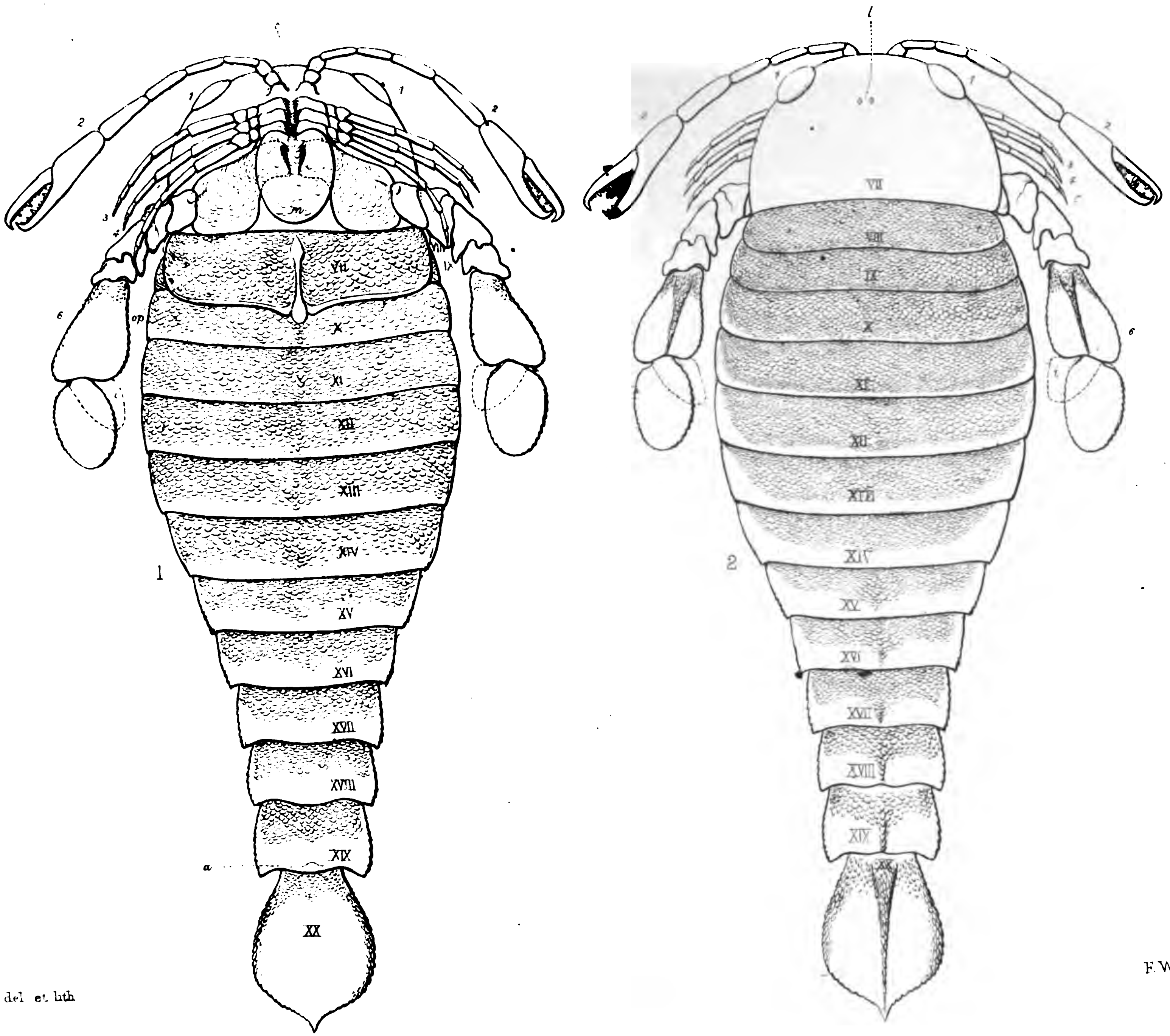
Sub-Order—EURYPTERIDA.

FIG.

1. Under side of ***Pterygotus anglicus***, Agassiz, restored.
2. Upper side of ditto.

Fig. 2. *l.* Larval eye-spots (*ocelli*).
„ 1. *m.* The metastoma or post-oral plate.
„ 1. *op.* The operculum (representing the coalesced pair of appendages belonging to the viith somite).
„ 1. *a.* Anal aperture.

Figs. 1, 2. 1. The eyes.
„ 2. The chelate antennæ.
„ 3. The mandibles (endognaths, Huxley).
„ 4. First maxillæ (ditto „).
„ 5. Second ditto (ditto „).
„ 6. Maxillipeds (ectognaths, „).
i, i. Position of small somewhat triangular plate united to the border of the penultimate joint, and overlapping the oval terminal palette. (See page 35.)
„ vii. The head-shield, bearing the *ocelli* (*l*) and large compound eyes (1, 1), and the operculum, or thoracic plate, which covers the two anterior thoracic somites (viii and ix) upon their ventral surfaces.
„ viii—xiv. Thoracic somites.
„ xv—xix. Abdominal somites.
„ xx. The 'telson' or terminal segment.



E Fielding del et lith

F. Waller imp

PTERYCOTUS ANGLICUS, *Agassiz.* *(Restored)*

PLATE IX.

ILLUSTRATIONS FROM RECENT CRUSTACEA.

FIG.

1. Under side of *Limulus polyphæmus*, ♀, from eastern shores of North America. One third natural size. Drawn from a dried specimen.
   1. The cephalic shield bearing the sessile eyes upon its upper surface. (The eyes, of course, cannot be seen in this view.)
   2. Inner or first antennæ or antennules.
   3. Second antennæ.
   4. Mandibles.
   5. First maxillæ.
   6. Second maxillæ.
   7. Maxillipeds.
   8. Operculum (covering reproductive organs).
   9—13. Branchial plates.
   14. Telson.

1 *a*. Modified antenna of male *Limulus polyphæmus*.
   1. Basal joint, with its palpus, *p*.

1 *b*. A detached maxilla of same, showing the palpus, *p*.

1 *c*. The operculum of *Limulus polyphæmus*, detached. The position of the ovaries is indicated by the dotted lines at *a*; *d*, *d*, detached articulated appendages, which in *Pterygotus* are welded together and form one coalesced median appendage, but remain bilobed at their extremity in *Eurypterus*.

2. *Calanus curtus*, Dana, ♀, 'United States Exploring Expedition,' *Crustacea—Cyclopoidea*, vol. xiv, part ii, p. 1059, Atlas, plate lxxii, fig. 10. Sooloo Sea, west of Panay, and Straits of Banca, east of Sumatra.

3. *Corycæus crassiusculus*, Dana, ♀, 'United States Exploring Expedition,' *Crustacea—Cyclopoidea*, part ii, vol. xiv, p. 1214, Atlas, plate lxxxv, fig. 7. Soloo Sea, west of the Island of Panay.

4. *Sapphirina ovato-lanceolata*, ♀, Dana, 'United States Exploring Expedition,' *Crustacea—Cyclopoidea*, part ii, vol. xiv, p. 1251, Atlas, plate lxxxvii, fig. 15. Atlantic, off the harbour of Rio Janeiro, lat. 23° S.; long., 41° West.

5. *Canthocamptus linearis*, ♀, Dana, 'United States Exploring Expedition,' *Crustacea—Cyclopoidea*, part ii, vol. xiv, p. 1188, Atlas, plate lxxxiii, fig. 9 *a*. From the sea, among the Fejee Islands.

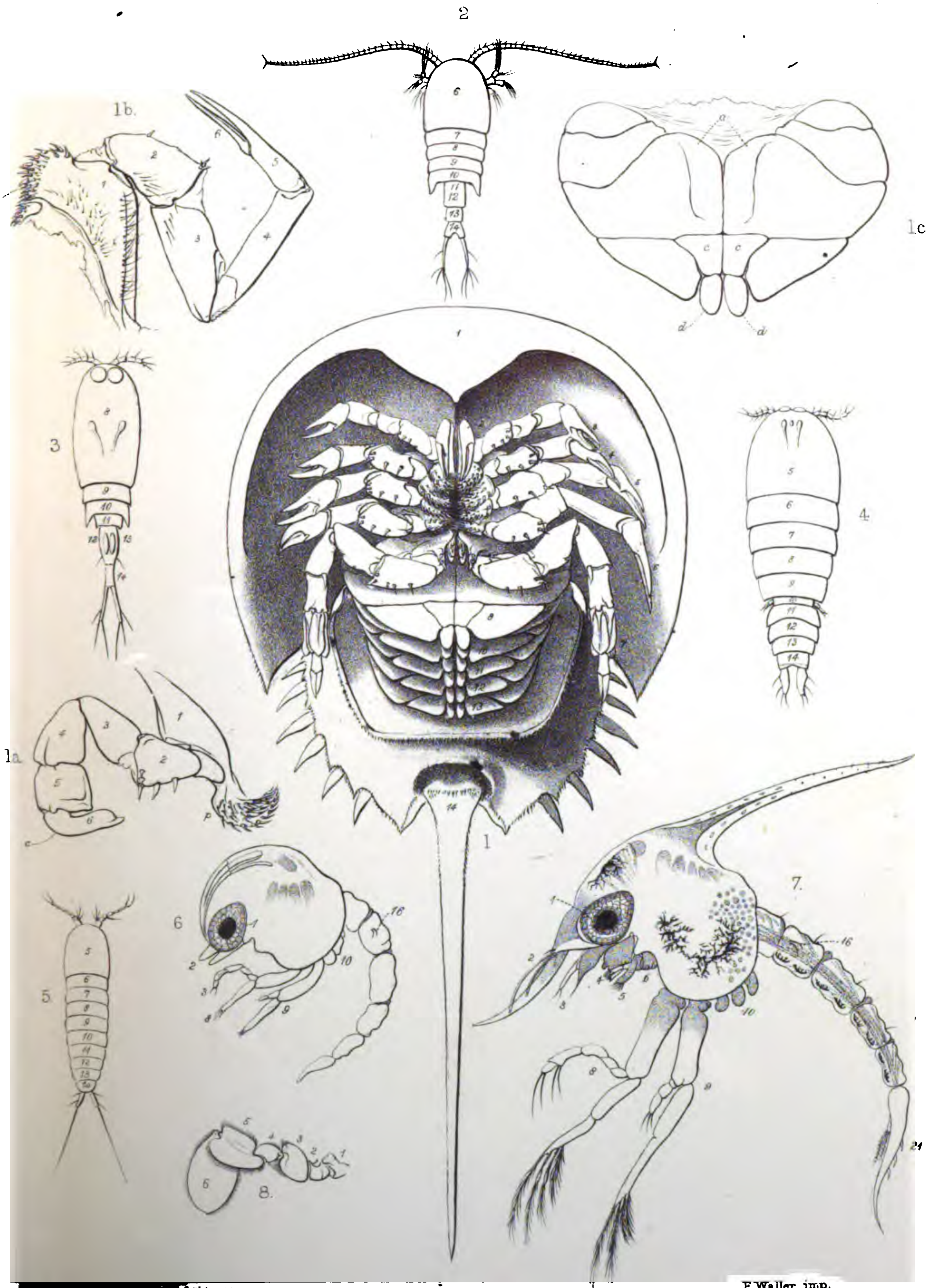
6. Larva, or *Zoëa*, of *Carcinus Mænas*, Penn., immediately as it quits the ovum.

7. Larva, or *Zoëa* of ditto, after the first moult.

Figs. 6 and 7 are copied from Mr. C. Spence Bate's paper on the "Development of Decapod Crustacea," Phil. Trans., 1858, p. 589, plate xl, figs. A and B.

   1. The eye.
   2. The anterior antenna.
   3. Posterior antenna.
   4. Mandibles.
   5. Anterior maxilla.
   6. Posterior maxilla.
   8. Anterior gnathopoda.
   9. Posterior gnathopoda.
   10. Rudiments of pereiopoda, or walking-legs.
   16. Indications of sexual character?
   21. Telson.

8. Swimming-foot of *Polybius Henslowi*.



E. Fielding del et lith.

F Waller imp.

PLATE X.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

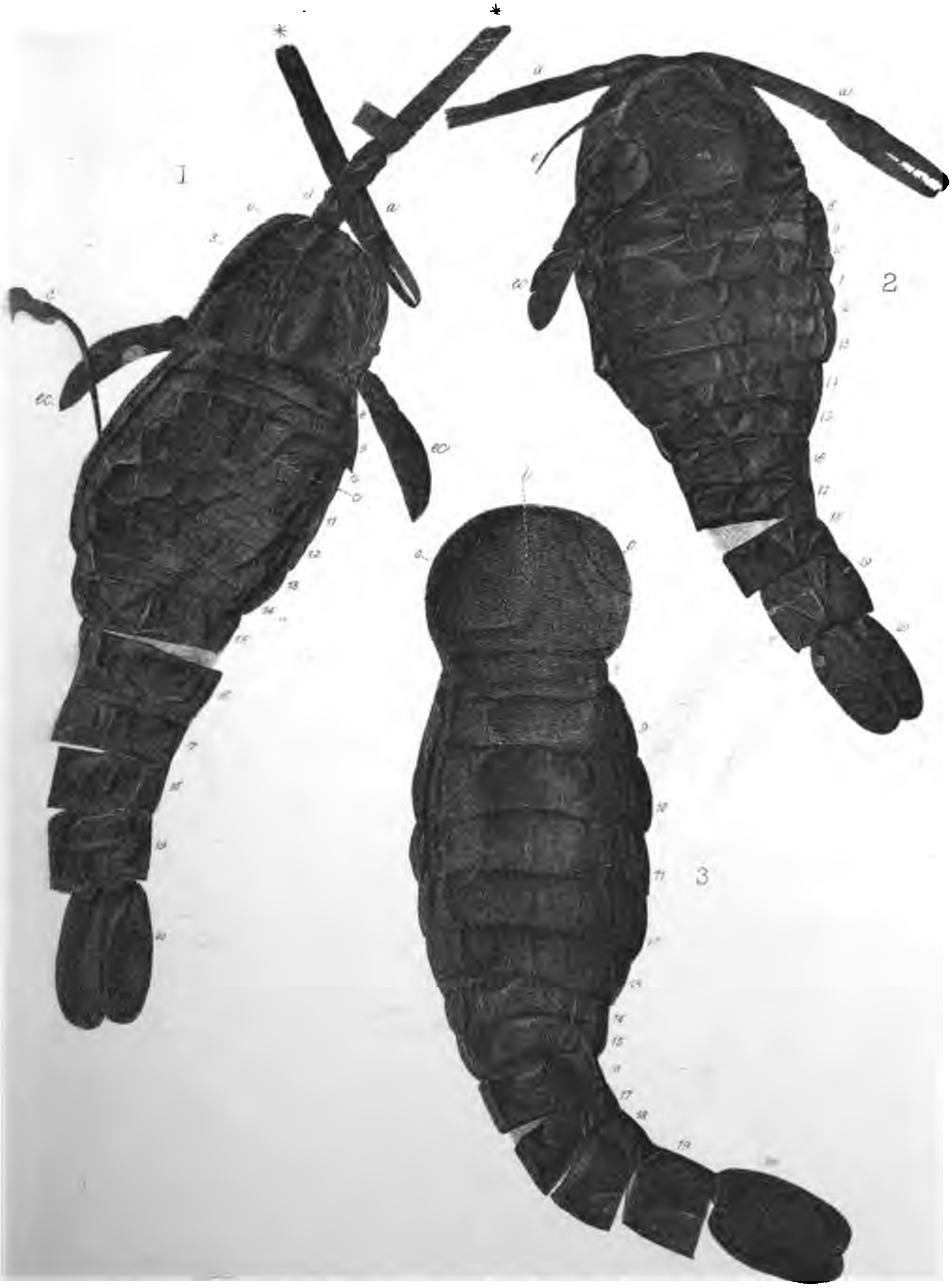
1—3. *Pterygotus bilobus*, Salter, var. *a*, *inornatus*.

1. Represents an almost entire example, having several of its appendages preserved.
    - *a, a.* The chelate antennæ, displaced (the stars indicate the proximal ends).
    - *o, o.* The large compound eyes.
    - *s, s.* The serrated mandibular borders of the basal joints of the maxillipeds or ectognaths (their general outline is seen through the carapace).
    - *ec, ec.* The ectognaths, with their broad, oar-like extremities.
    - *e.* One of the small endognaths, preserved entire, but lying on the slab detached from the head.
    - *c.* The narrow median lobe of the thoracic plate (the impression seen through the overlying somites).
2. An almost equally well-preserved specimen. The antennæ (*a, a*) are still attached in their normal position to the anterior border of the head-shield. One of the endognaths (*e*) and an ectognath (*ec*) are still *in situ*; the metastoma or post-oral plate (*m*) is clearly seen.
3. Exhibits well the large compound eyes (*o, o*) and the larval eye-spots or *ocelli* (*le*). All the appendages have been detached from this specimen, and lie at a little distance from it upon the same slab (they are represented in the Woodcut, p. 58).

N.B.—The small figures placed against the body-segments in all these plates correspond throughout with the small Roman numerals placed against the segments of the restored figures of *Pt. anglicus*, given in Part I, Pl. VIII, of this Monograph.

From the Uppermost Silurian formation of Lesmahago, Lanarkshire.

Drawn, of the natural size, from specimens in the British Museum.



A. T. Hollick, Del et Lith.

F. Waller Imp

PTERYGOTUS BILOBUS, *Salter.* (*var a.*)

PLATE XI.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1. *Pterygotus bilobus*, var. *β*, *crassus*.

o, *o*. The compound eyes.

s. The serrated mandibular border of one of the ectognaths.

ec, *ec*. The ectognaths, preserved *in sitû*.

e. One of the endognaths, displaced.

a. A chelate antenna; the claw or pincer hidden beneath the telson.

2 *a*. Seven of the anterior segments of *Pt. bilobus* var. *γ*, *perornatus* (= var. *plicatissimus*, Salter).

op. The opercular plate, squeezed forward and much distorted.

c. The central appendage of same.

br. The branchiæ exposed to view, protruding from beneath the upper and originally attached border of the operculum.

2 *b*. The above described portion of 2 *a*, magnified twice (the letters are the same as in fig. 2 *a*, above). [The direction of the plicæ upon the operculum indicates that the *lower* edge in our Plate was that by which it was originally attached to the posterior border of the under side of the head. The head, and probably the first two body-segments, are wanting.]

3. Detached antennæ of a very large *Pterygotus* (probably *Pt. bilobus*, var. *γ*).

ch. The moveable chela, with its large teeth, resembling those of *Pt. anglicus* (see Part I, Pl. VII, figs. 1—3).

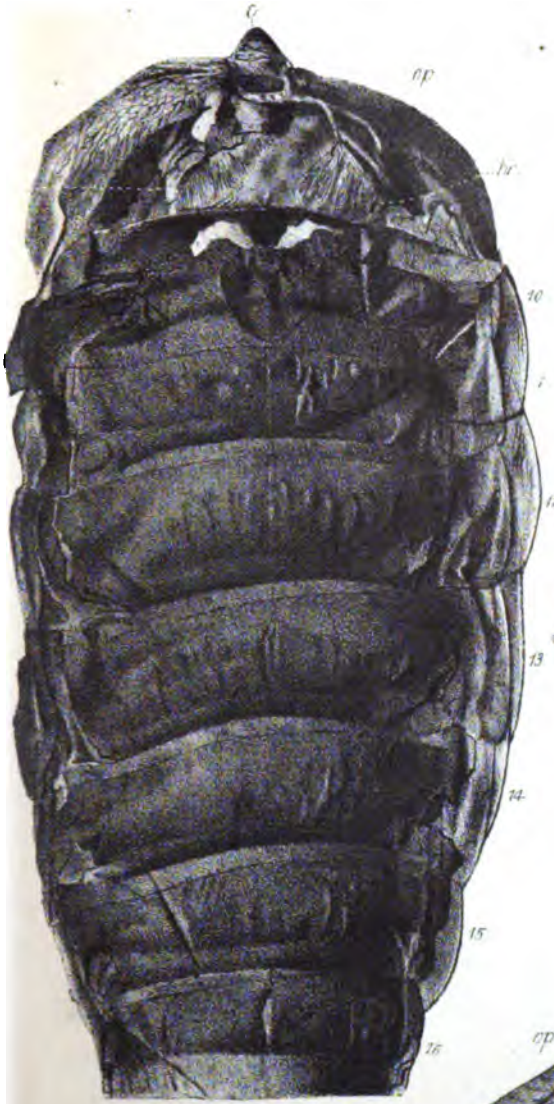
The surface at B is covered with the valves of *Beyrichia Klœdeni* or *gibba* (a small bivalved Entomostracan), a pair of which are enlarged and figured at B 1.

Figs. 1, 2 *a*, and 3, are drawn of the natural size; fig. 2 *b* magnified twice; fig. B 1 magnified six times.

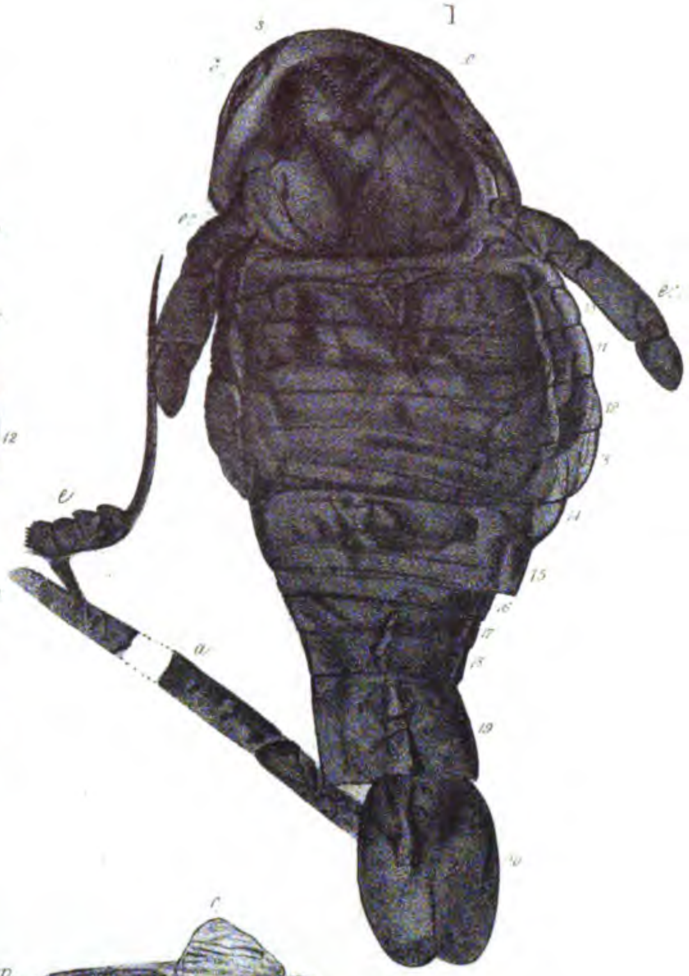
From Uppermost Silurian of Lesmahago, Lanarkshire.

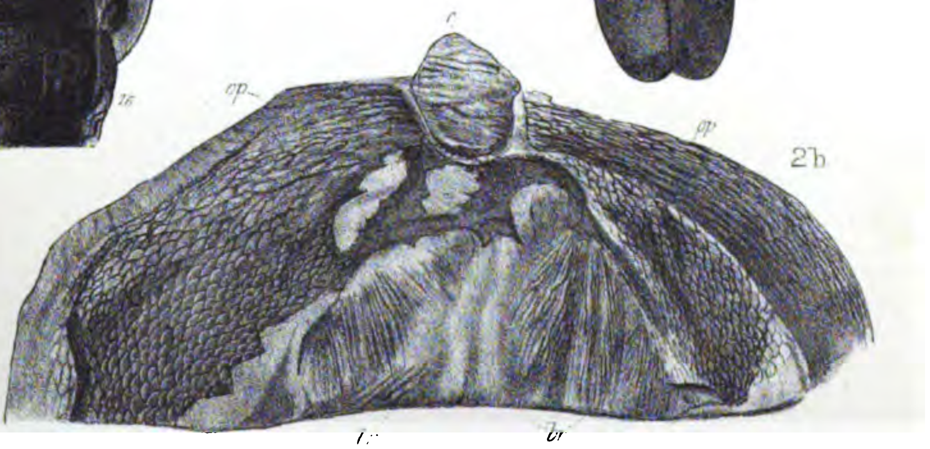
Figs. 1 and 3 are in the British Museum. Fig. 2 is in the Museum of Practical Geology, Jermyn Street.

2 a.



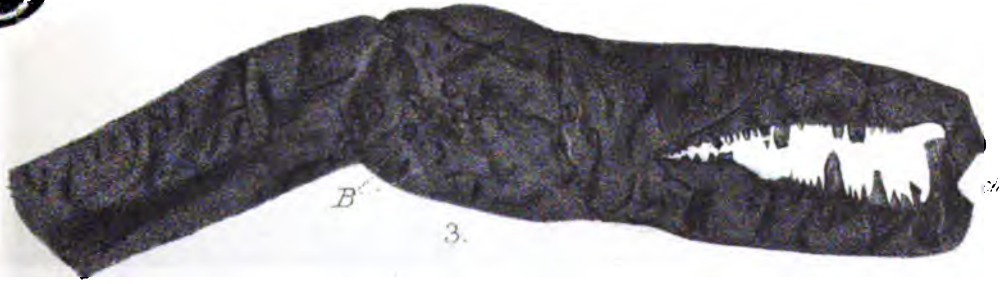
1





2b

B1.



3.

A.T. Hollick Del et Lith

F Waller Imp

Fig 1 PTERYCOTUS BILOBUS, *Salter. (var β)* *Fig 2. (var. γ)*

Fig. 3. Detached chelate Antenna of Pterygotus.

PLATE XII.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Pterygotus bilobus, var. δ, *acidens*.

FIG.

1 *a*. Represents an individual of the natural size.
- *le*. The larval eye-spots.
- *o, o*. The compound eyes.
- *a*. One of the antennæ.
- *m*. The metastoma, or post-oral plate.
- *ec*. One of the ectognaths.
- *op*. The operculum (*c*, its central portion).
- *br*. Some of the branchiæ.

The segments marked 15 and 16 are absent in the specimen.

1 *b*. Antenna, magnified twice the natural size; *m*, moveable ramus of chela.

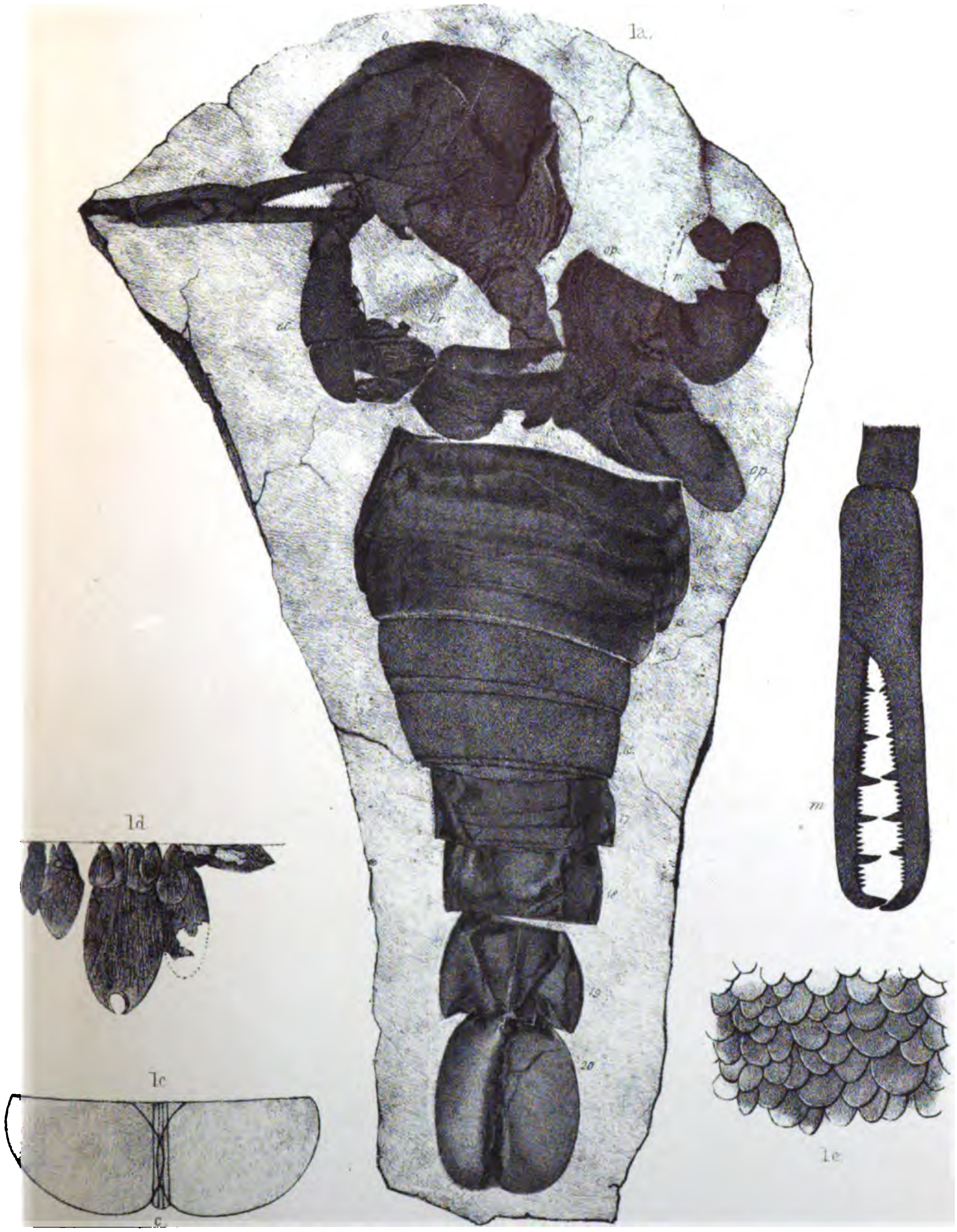
1 *c*. Some of the scale-like markings upon the surface of the thorax, greatly magnified.

1 *d*. Some of the branchiæ, enlarged twice the natural size.

1 *e*. Thoracic plate restored (natural size).

From the Uppermost Silurian of Lesmahago, Lanarkshire.

Drawn from a specimen in the Museum of Practical Geology, Jermyn Street.



A I Hollick Del et Lith

T Walker Imp

PTERYGOTUS BILOBUS. *Salter.* (*var δ*)

U. Silurian of Lanarkshire.

PLATE XIII.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Pterygotus bilobus, var. γ, *perornatus*.

FIG.

1 *a*. An almost entire example, reduced to one half the natural size.

a, a. The antennæ, detached and displaced (the points of attachment to the head are marked by stars).

o, o. The eyes; and (*le*) the larval eye-spots or ocelli.

e. An endognath and part of another, displaced.

ec. The ectognaths, or swimming-feet; their great basal joints (*c, c*) are detached, and lie in front of the head.

m. The metastoma or post-oral plate.

The telson (20) is restored.

1 *b*. The larval eyes, magnified three times.

1 *c*. One of the large compound eyes, magnified three times.

1 *d*. A portion of same, magnified fifteen times.

1 *e*. The metastoma, of the natural size.

1 *f*. The coxal joint of one of the ectognaths, natural size.

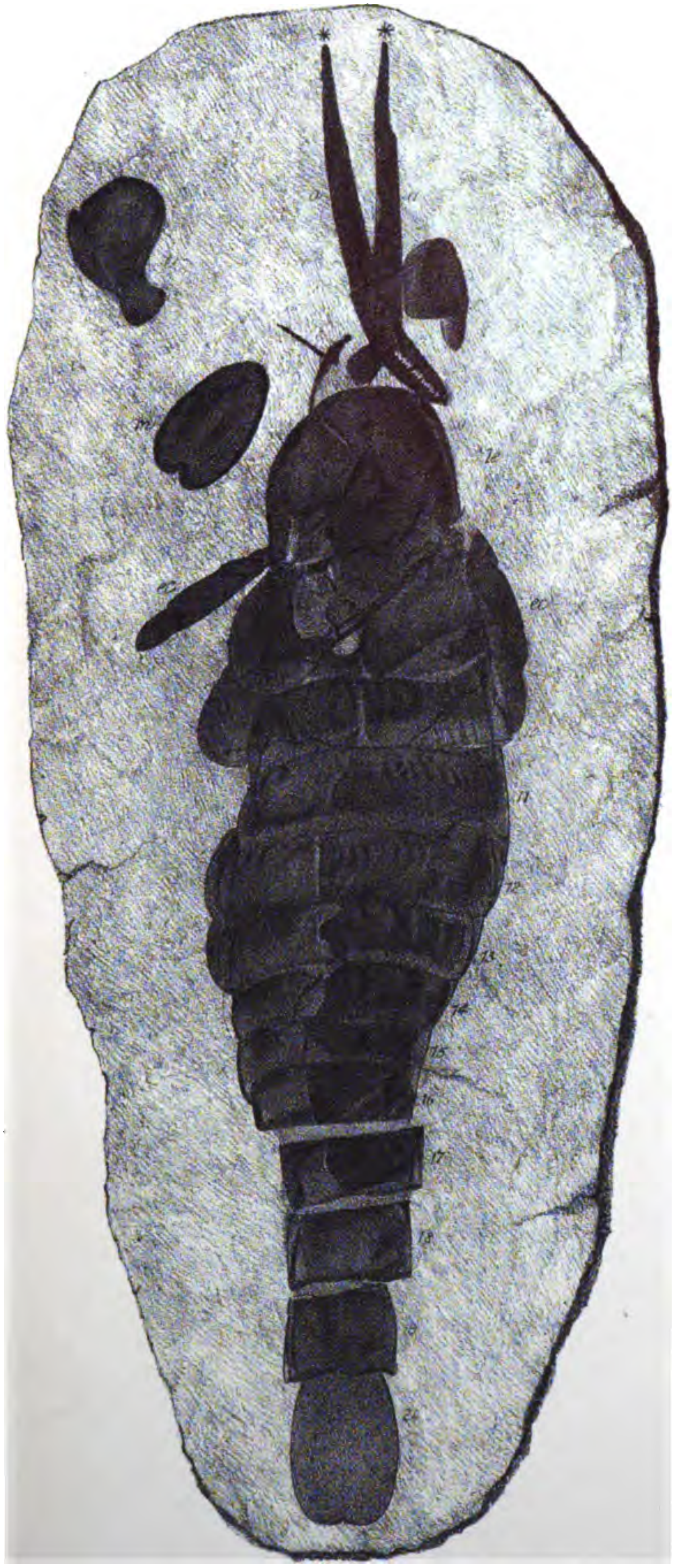
1 *g*. Part of a thoracic segment, magnified three times, to show the scale-like markings on its upper part.

1 *h*. Three of the branchiæ, magnified three times, seen in this specimen where a portion of a thoracic segment has been removed.

From the Uppermost Silurian of Lesmahago, Lanarkshire.

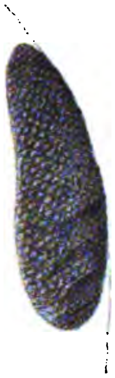
Drawn from a specimen in the Museum of Practical Geology, Jermyn Street.

1 a.



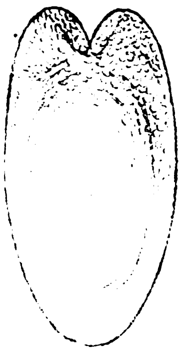
1b

1c

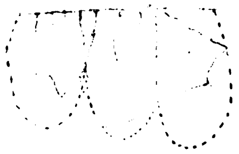


1d

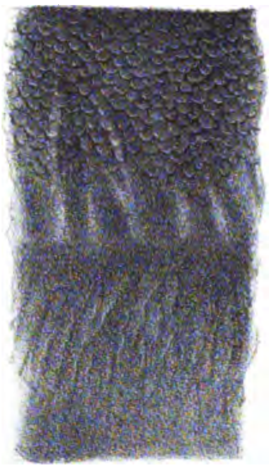
1e



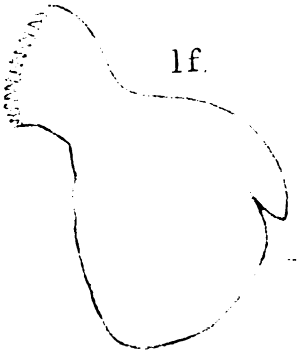
1h



1 g.



1f.



A. [illegible], Del et lith.

F. Waller, Imp.

PTERYGOTUS BILOBUS, *Salter* (*var. γ.*)

PLATE XIV.

UPPER SILURIAN CRUSTACEA.

Order—Merostomata.

Sub-Order—Eurypterida.

Fig.

1. *Pterygotus bilobus*, var. γ, *perornatus*.

1 *a*. Head, with the great maxillipeds or ectognaths still attached, but displaced outwards on either side.

The form of the head-shield, the compound facetted eyes (*o*, *o*), and the larval eyes (*le*) are well seen. The joints of the ectognaths are lettered to correspond with the names given to the articuli (see page 6, Part I).

1 *b*. Facets of eye, magnified ten times.

1 *c*. Facets of eye, magnified six times.

(The form is evidently altered by compression.)

1 *d*. Scale-like markings from the right coxal joint, magnified four times.

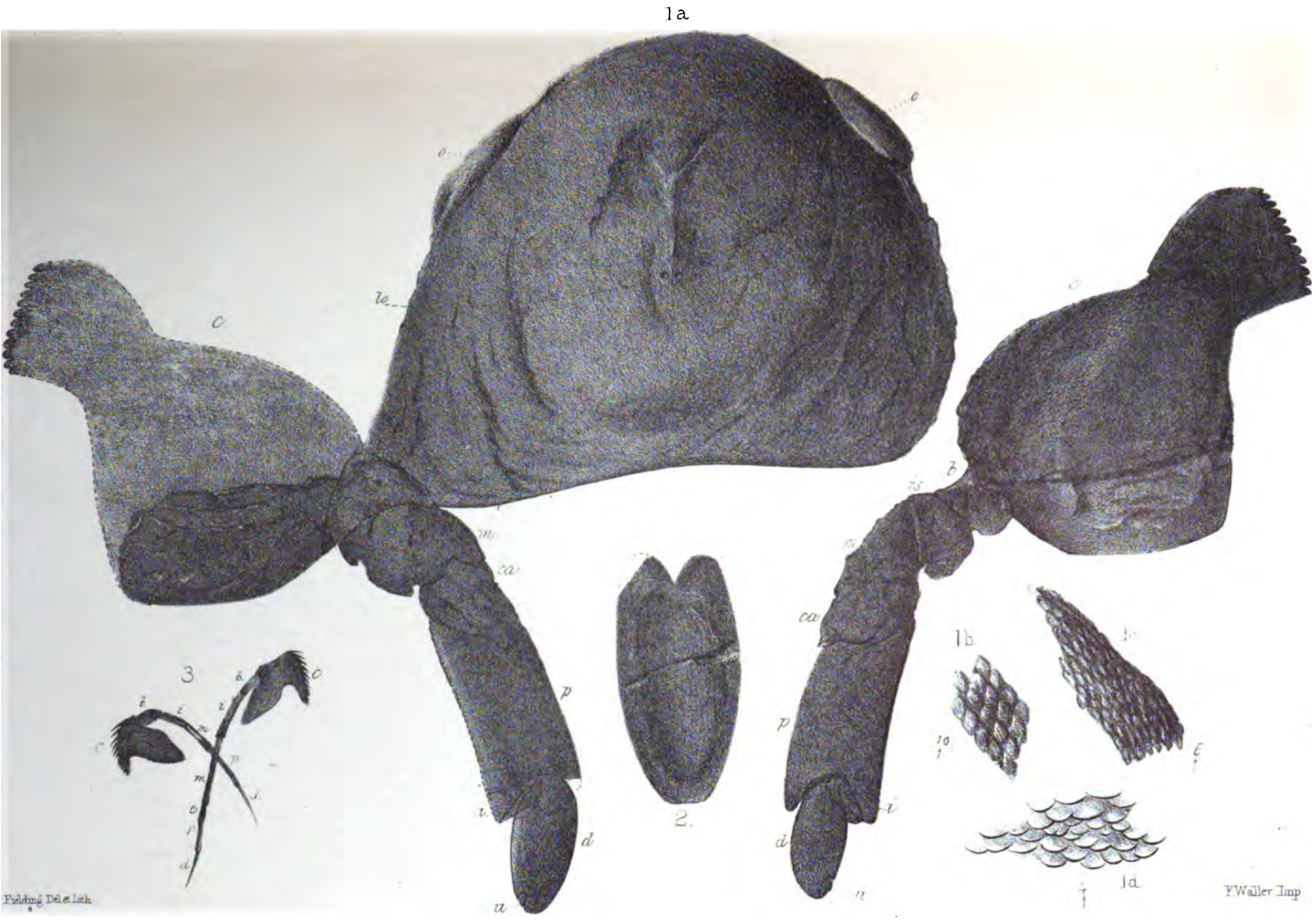
(The upper portion of the left coxal joint is restored.)

2. A detached lip-plate, showing the lower edge (near the figure 2) to be truncated. (See also Pl. XV, fig. 3.)

3. Two beautifully preserved endognaths, found detached (the joints are lettered as in fig. 1).

From the Uppermost Silurian of Lesmahago, Lanarkshire.

Figs. 1 *a*, 2, and 3 are drawn, of the natural size, from specimens preserved in the Museum of Practical Geology, Jermyn Street.



E. Fielding Del et Lith

F. Waller Imp

PTERYGOTUS BILOBUS, (var. γ) PERORNATUS, &c.

Uppermost Silurian of Lanarkshire

PLATE XV.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

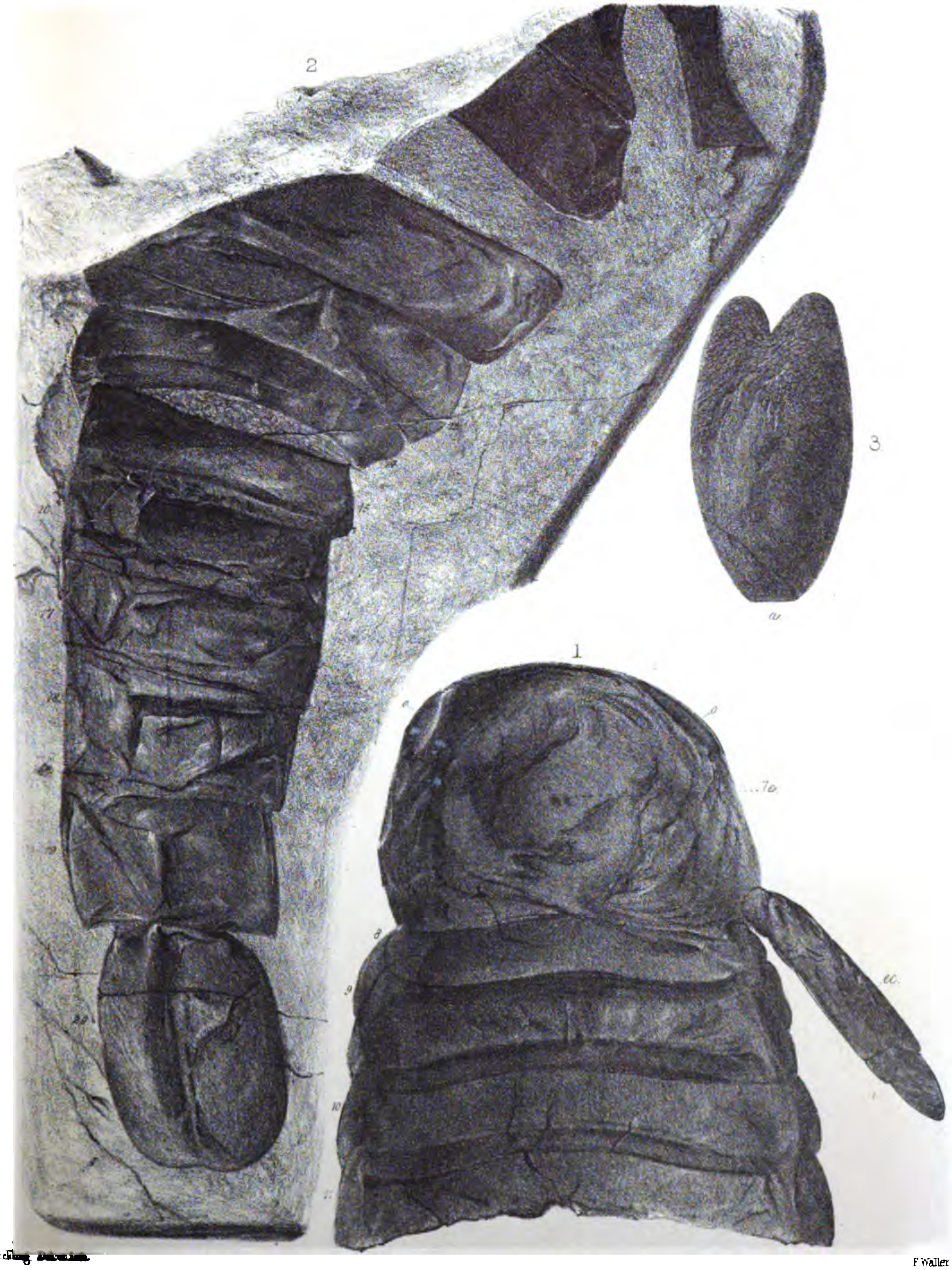
Pterygotus bilobus, var. γ, *perornatus*.

FIG.

1. Head and four anterior segments of body of *Pt. bilobus*, var. γ, showing the larval eyes (*le*), the compound eyes (*o, o*), and the right swimming-foot (ectognath), still attached *in sitû*.
2. The greater part of the body of another specimen, having portions of the thoracic and the entire series of abdominal somites preserved.
3. A very beautifully preserved detached lip-plate of *Pt. bilobus*, var. γ, showing the truncated posterior border (*a*), by which it was attached to the head. The surface is beautifully squamate.

From the Uppermost Silurian of Lesmahago, Lanarkshire.

Drawn, of the natural size, from specimens preserved in the British Museum.



E. F[illegible]

F. Waller imp.

PTERYGOTUS BILOBUS, *(var. γ.)* PERORNATUS.

U. Silurian of Lanarkshire.

PLATE XVI.

UPPER SILURIAN AND DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1. *Pterygotus raniceps*, H. Woodw. U. Ludlow Rock, Lesmahagow, Lanarkshire. (Drawn from the original specimen in the British Museum.) P. 71.
2. *Pterygotus Banksii*, Salter. The carapace from the Passage Beds at the Ludlow Railway Station. (In Mr. Lightbody's Cabinet.) Pp. 72—74.
3. *Pterygotus Banksii*, head of a very young individual. Downton Sandstone, Kington. (Mr. Banks's Cabinet.)
4. *Pterygotus Banksii*. The posterior segments of the body, with the telson. Passage Beds, Railway Station, Ludlow. (From Mr. Lightbody's Cabinet.)
5. *Pterygotus Banksii*. The anterior half of the body, exhibiting the carapace, six thoracic segments, and the left ectognath or swimming-foot. Upper Ludlow Rock. (Mr. Lightbody's Cabinet.)
6. A metastoma or post-oral plate. Upper Ludlow Rock. (Mr. Lightbody's Cabinet.)
7. *Pterygotus ludensis*, Salter. Posterior portion of body, reduced to two thirds. P. 76.
8. *Pterygotus problematicus?* A penultimate body-segment, showing the short *dorsal* ridge—not *sternal*, as supposed by Mr. Salter.—H. W. (From Mr. Lightbody's Cabinet.) P. 77.

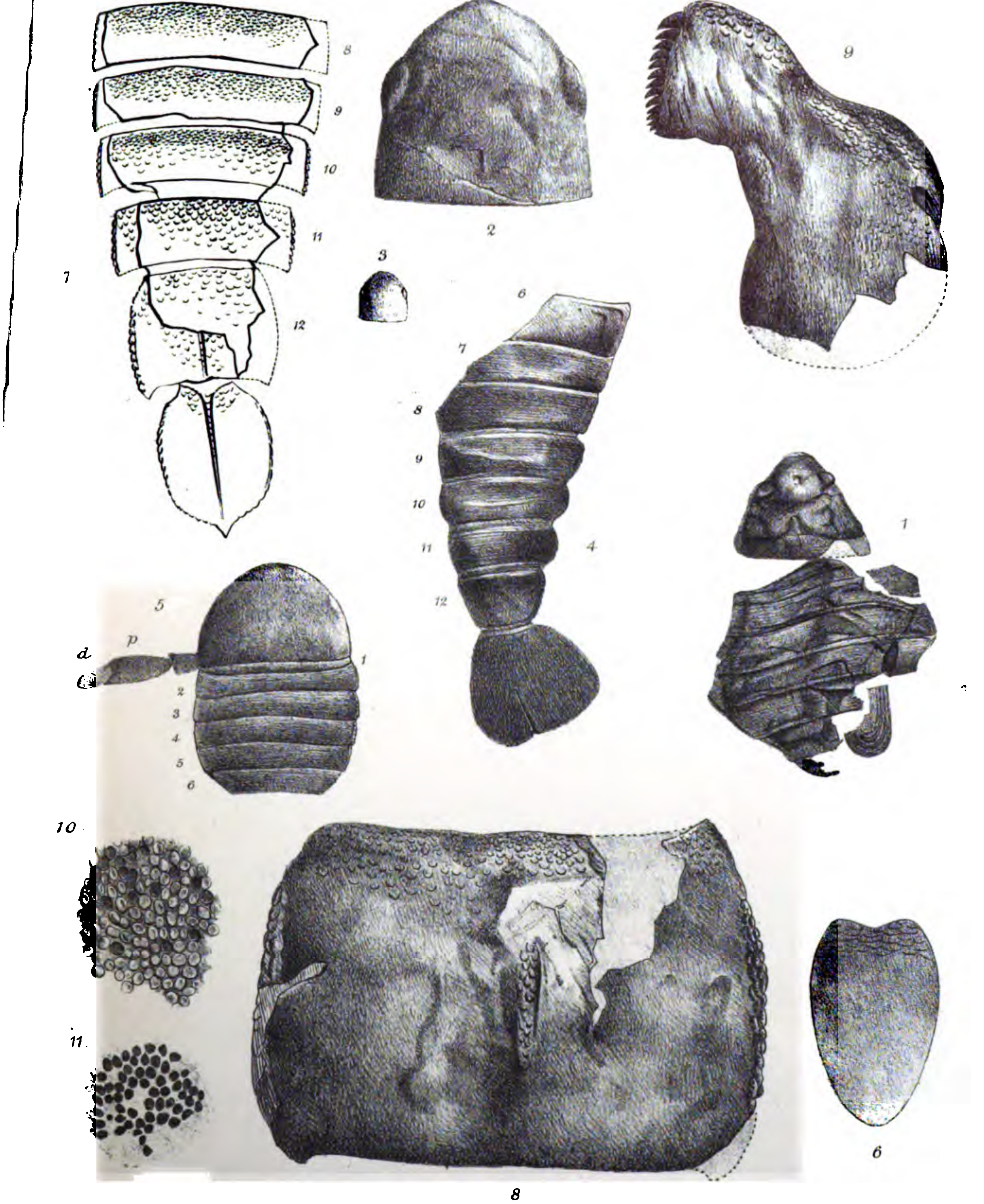
   Mr. Salter remarks: "Perhaps this represents only a variety of *P. ludensis*."
9. *Pterygotus ludensis*, Salter. Basal joint of an ectognath, with short serrations. (Mr. Lightbody's Cabinet.)
10. *Parka decipiens*, Fleming. *Ova* of *Pterygotus*. P. 79.
11. This specimen shows the eggs in section, as black carbonaceous spots, whereas in Fig. 10 the external surface and rounded form of many are well preserved.

    If these eggs were enclosed, like those of the modern *Limulus*, in a hard and horny exchorion, and deposited in the sand in the same manner, we have at once a simple explanation furnished us of their abundance in certain beds.

Figs. 10 & 11 are drawn from specimens obtained by the late Mr. Baugh, and preserved in the British Museum, from the base of the Old Red Sandstone at Trimpley, north of Bewdley.

With the exception of Figs. 1, 10, and 11, these are all re-drawn from Mr. C. R. Bone's excellent figures in plates xii and xiv of Messrs. Huxley and Salter's Monograph on the Eurypteridæ. ('Mem. Geol. Surv.,' Mon. I, 1859.)

U. SILURIAN CRUSTACEA.



A. T. Hollick. del. et lith. W West imp.

Remains of PTERYGOTUS *Raniceps, P. Banksii.*
P. Ludensis &c.

PLATE XVII.

UPPER SILURIAN CRUSTACEA.

Order—Merostomata.

Sub-Order—Eurypterida.

Figs. 1—4.—*Slimonia acuminata*, Salter, sp. P. 105.

Fig.

1. This is by no means the largest, but it is one of the most perfect, specimens met with by Mr. Robert Slimon at Lesmahagow. Both the intaglio and relievo are now preserved in the British Museum.

   The specimen exhibits its ventral aspect.

   The small letters and figures refer to the same parts and organs as indicated in Parts I & II of this Monograph.

2. A detached thoracic plate, exhibiting the tricuspid termination of the median lobe (*c*). From a specimen in the British Museum. P. 114.

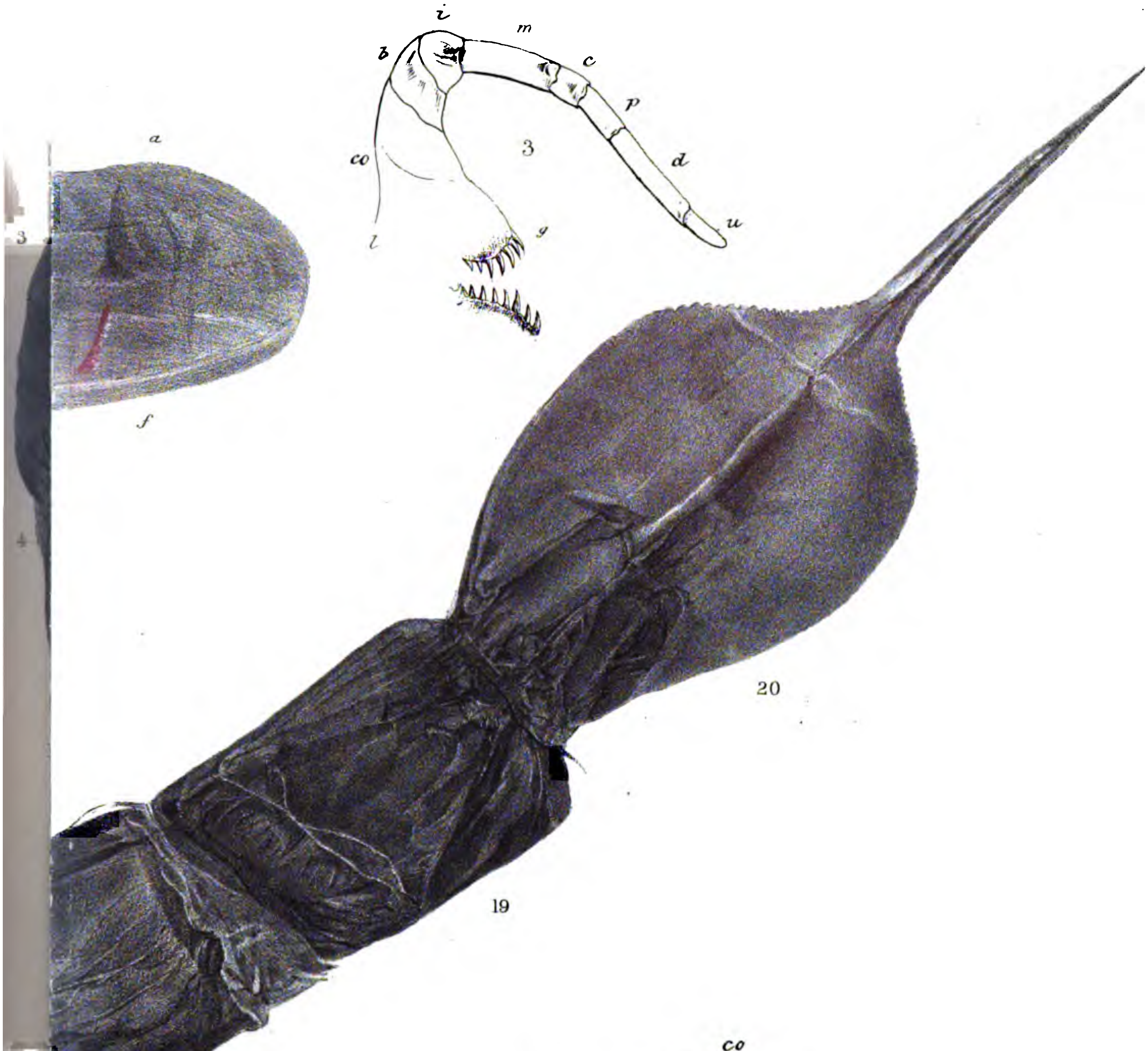
3. One of the antennæ, with its serrated basal joint, and also that of the opposing maxilla. P. 109.

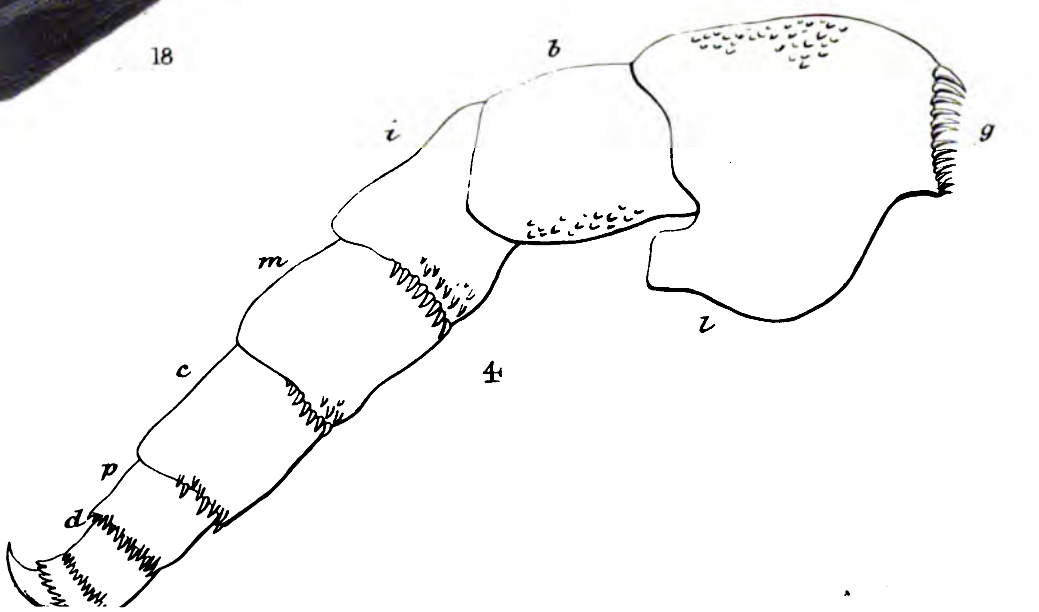
4. One of the endognaths. The mandible in this specimen is turned the reverse way. P. 111.

All drawn of the natural size from specimens in the British Museum.

Formation.—Uppermost Ludlow Rock.

Locality.—Lesmahagow, Lanarkshire.





W West imp

PLATE XVIII.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Figs. 1, 2.—*Slimonia acuminata,* Salter, sp. P. 105.

FIG.

1. The appendages detached from the head, but otherwise found entire, as represented.

   The lip-plate, the great swimming-feet, the endognaths, and even the antennæ, are preserved.

   The specimen is drawn two thirds the natural size.

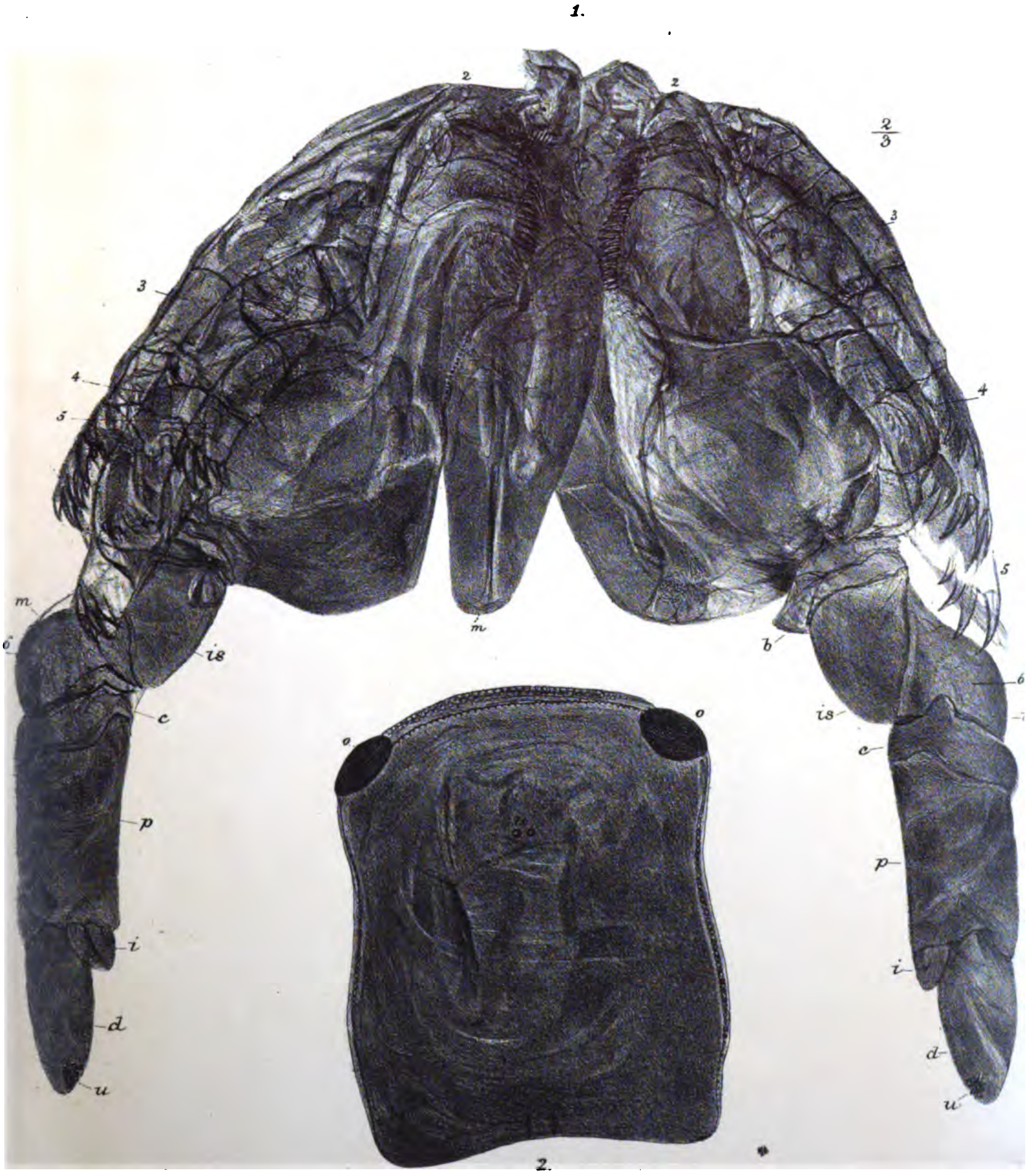
2. A detached head-shield belonging to a young individual. P. 106.

   The large compound eyes (*o*, *o*) and the larval eye-spots (*l e*) are well seen.

   Drawn of the natural size. From specimens in the British Museum.

   Formation.—Uppermost Ludlow Rock.

   Locality.—Lesmahagow, Lanarkshire.



From nat. on stone by J. Erxleben.
W. West imp

SLIMONIA ACUMINATA. *Salter. sp.*

PLATE XIX.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Figs. 1—4.—*Slimonia acuminata*, Salter, sp. P. 106.

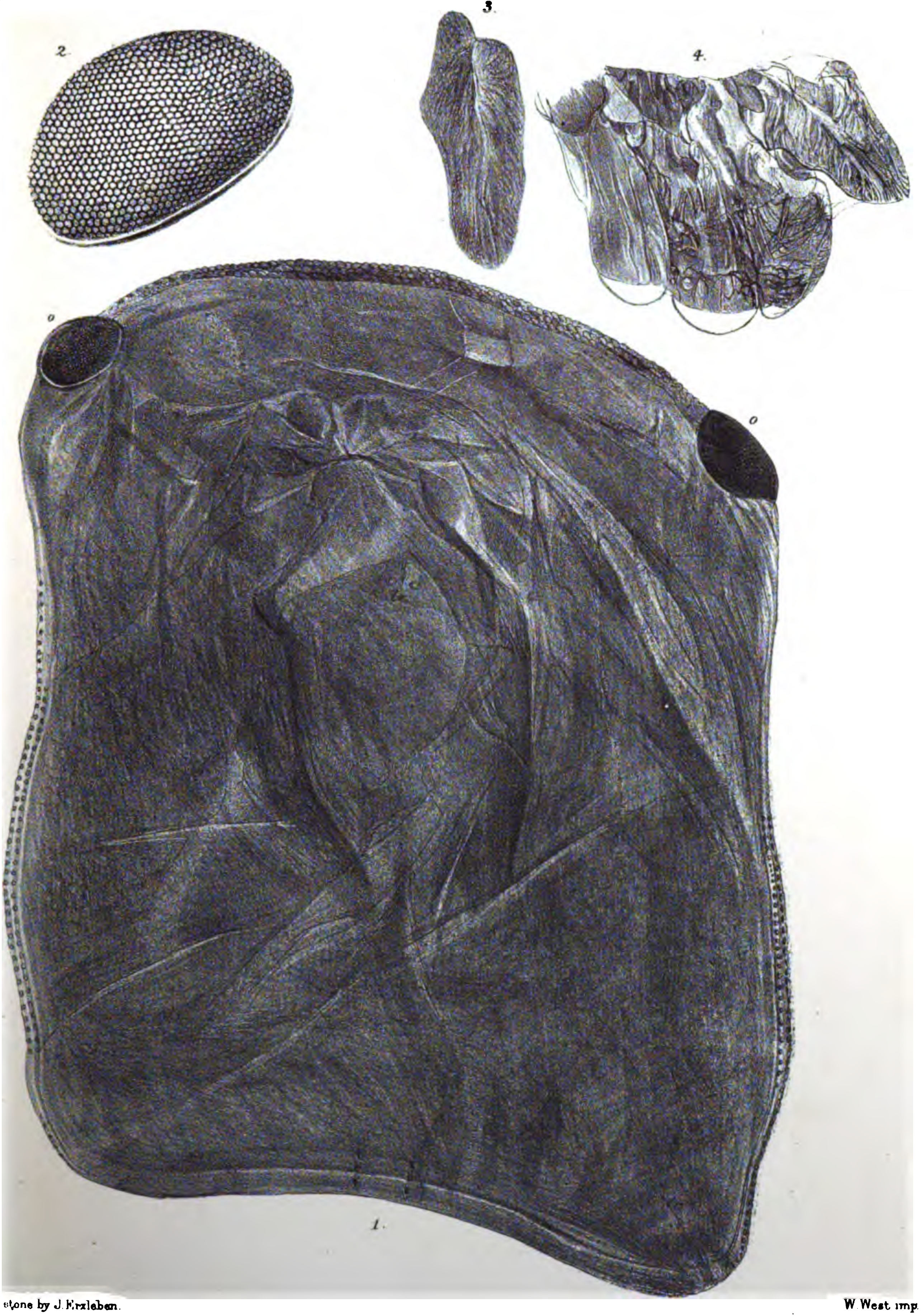
FIG.

1. The largest perfect head-shield known.
   (*o*, *o*), the compound eyes.
   (*l*, *e*), larval eye-spots.
   Drawn the natural size.
2. One of the compound eyes of a small individual, enlarged four times in order to show the facets.
3. A detached leaflet from the branchiæ of the natural size. P. 115.
4. A series of branchiæ preserved united. Drawn of the natural size. P. 115.

From specimens in the British Museum.

Formation.—Uppermost Ludlow Rock.

Locality.—Lesmahagow, Lanarkshire.



from nat on stone by J. Erxleben.

W West imp.

SLIMONIA ACUMINATA *Salter sp.*

PLATE XX.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Figs. 1—4.—*Slimonia acuminata,* Salter, sp. P. 105.

FIG.

1. Upper side. Restored.
2. Under side. „
3. Median appendage of thoracic plate or operculum (male ?).
4. Ditto (female ?).

Segments I—VI. Cephalic.[1]

„ VII—XIII. Thoracic.[2]

„ XIV—XX. Abdominal.[3]

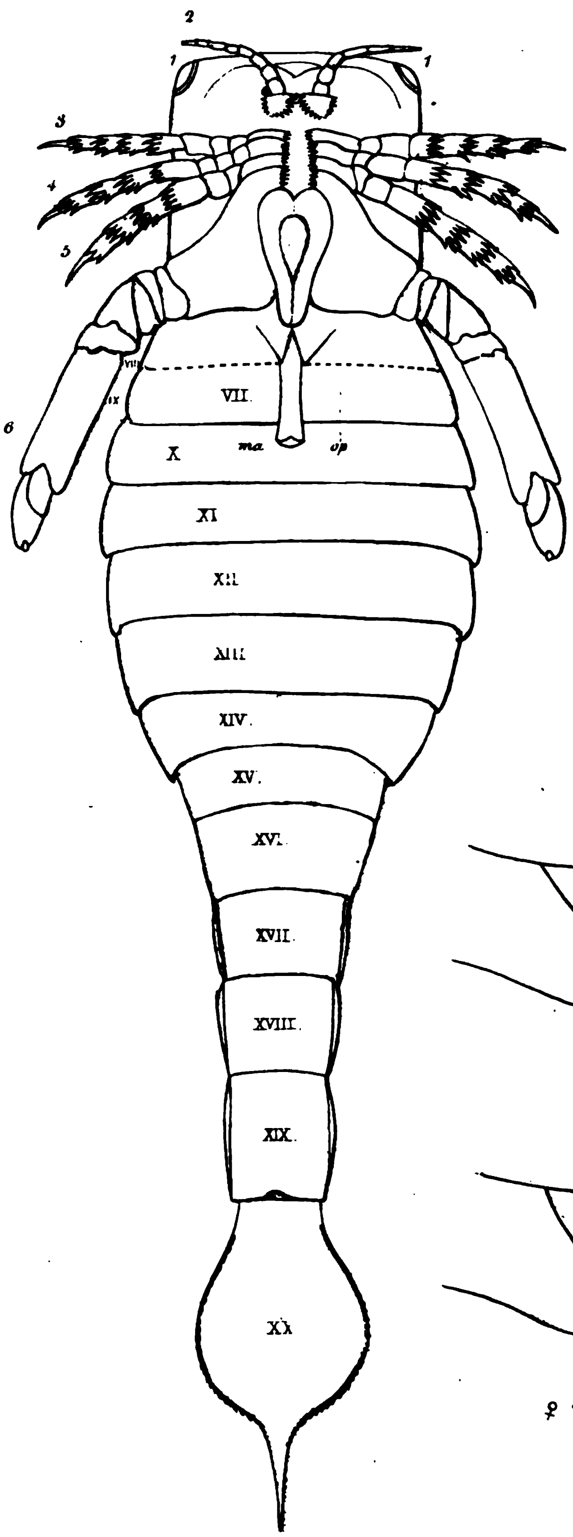
---

[1] One cephalic segment (that bearing the antennules) is suppressed in the Eurypteridæ.

[2] The first thoracic segment bearing the thoracic plate or operculum is coalesced with the head-shield both in *Limulus* and in *Pterygotus*, &c.

[3] In the explanation to Plate VIII, the 14th Segment is included as thoracic; this is an error, and should be corrected.

2



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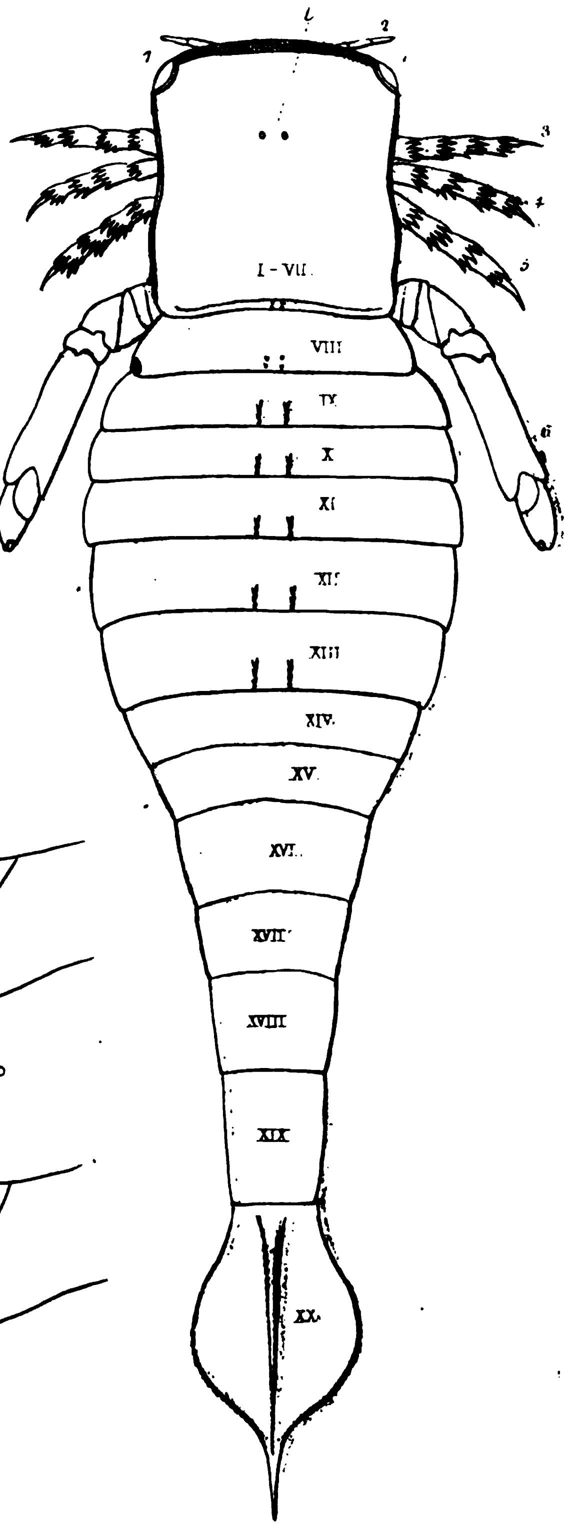

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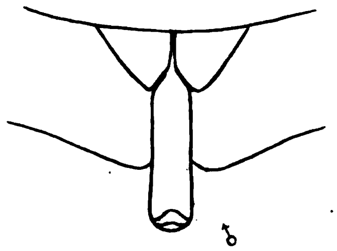
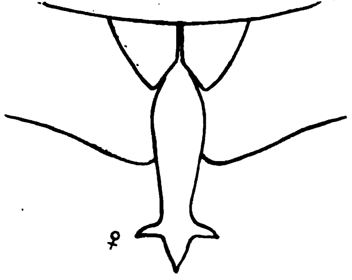


4



A. T. Hollick, del. et lith. W. West imp.

SLIMONIA ACUMINATA, *Salter, sp.*

(*Restored.*)

PLATE XXI.

DEVONIAN AND SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1. *Stylonurus Powriei,* H. Woodw., nat. size.
   Old Red Sandstone; Turin Hill Range, near Pitscandly, Forfarshire. (P. 122.)
   From the Collection of James Powrie, Esq., F.G.S., Reswallie.

2. *Stylonurus Powriei ?* two detached swimming feet of large size, probably belonging to this species. (P. 123.)
   Upper Silurian; Lesmahagow, Lanarkshire.
   From the Collection of James Powrie, Esq., F.G.S.

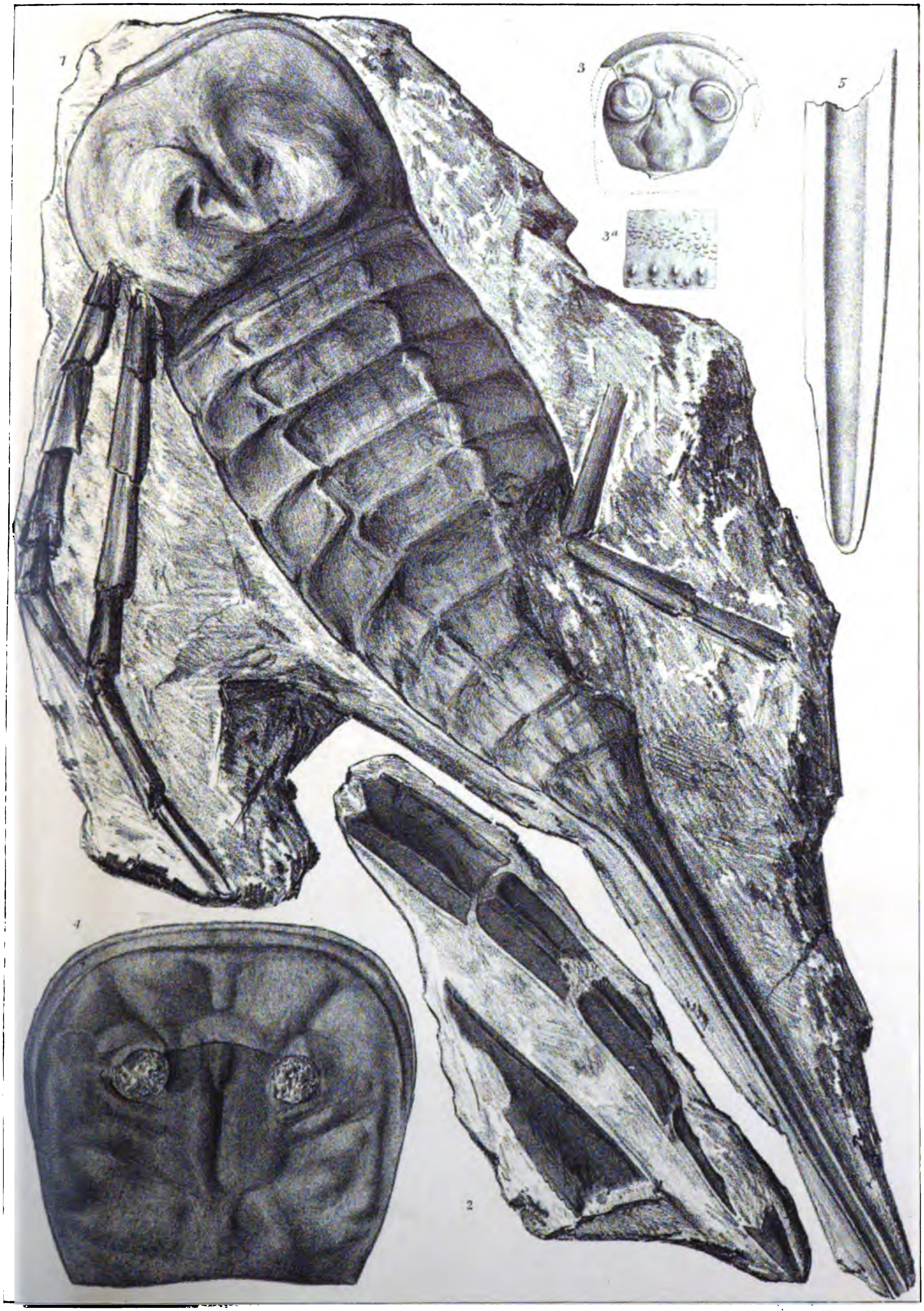
3. *Stylonurus megalops,* Salter, sp. Head-shield, nat. size. (P. 124.)

3 *a*. „ „ part of the head magnified, showing the granular surface.
   From the Collection of Robert Lightbody, Esq., F.G.S., Ludlow.

4. *Stylonurus Symondsii,* Salter, sp. (P. 124.)
   Upper Beds of the Cornstones, Old Red Sandstone; Rowlestone, Brecknockshire.
   Head-shield, nat. size.
   From the Museum of Practical Geology, Jermyn Street.

5. *Stylonurus ensiformis,* H. Woodw. Tail-spine, nat. size. (P. 126.)
   Old Red Sandstone ; Turin Hill Quarries, Forfarshire.
   From the Collection of James Powrie, Esq., F.G.S.

SUB-ORDER EURYPTERIDA.



[illegible] Mintern Bros. imp.

PLATE XXII.

DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

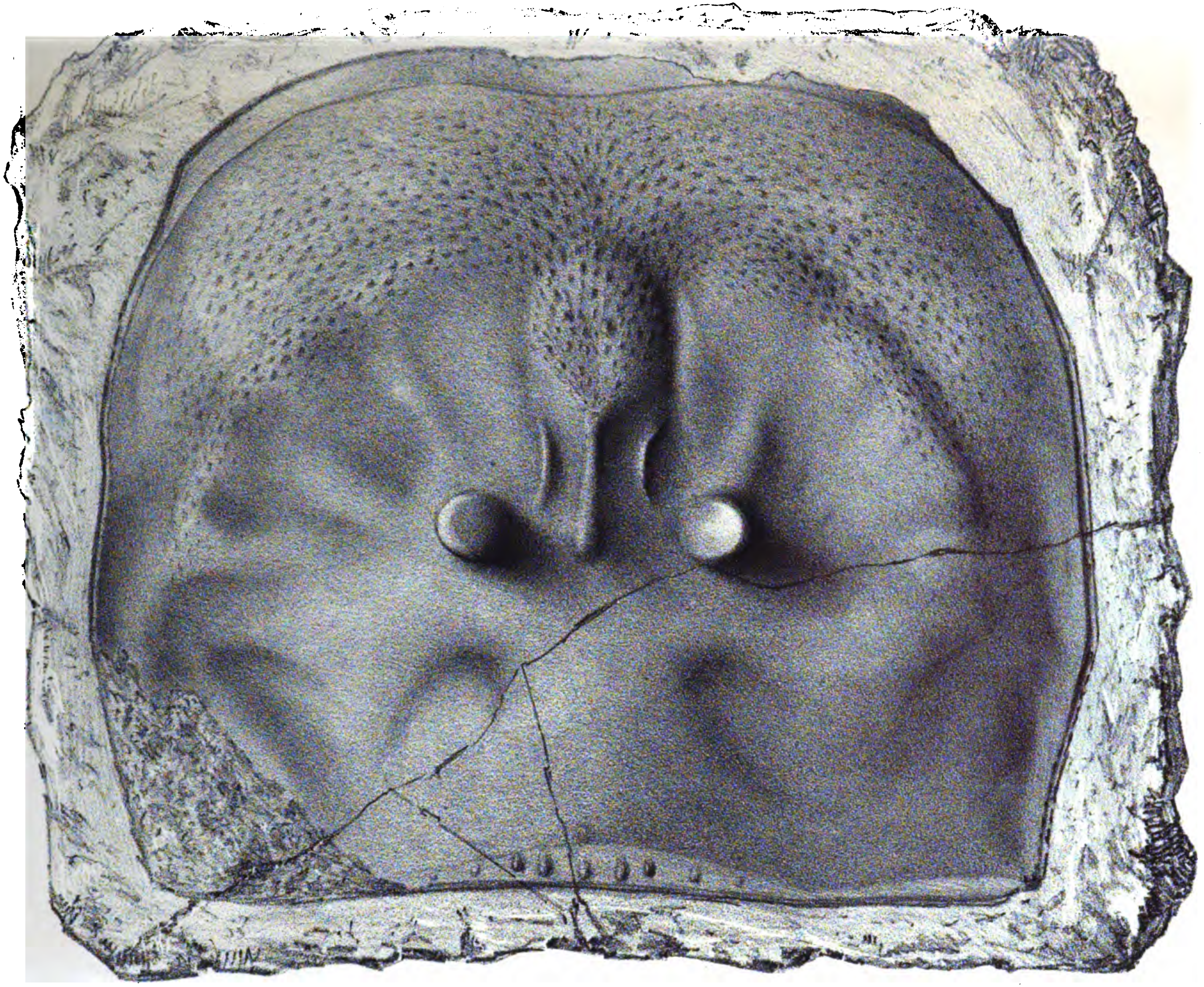
Stylonurus Scoticus, H. Woodw. (P. 126.)

Cast, in Grey Sandstone, of the inner surface of the head-shield; natural size.

From the Old Red Sandstone Quarry, Montroman Muir, near the Forfar and Montrose Pike.

The *intaglio* half (showing the inside of the carapace itself) is preserved in the British Museum.

The *relievo* is in Lady Kinnaird's Cabinet, Rossie Priory.



C. L. Griesbach del et lith

Mintern Bros imp

STYLONURUS SCOTICUS, *H. Woodward.*

PLATE XXIII.

DEVONIAN CRUSTACEA.

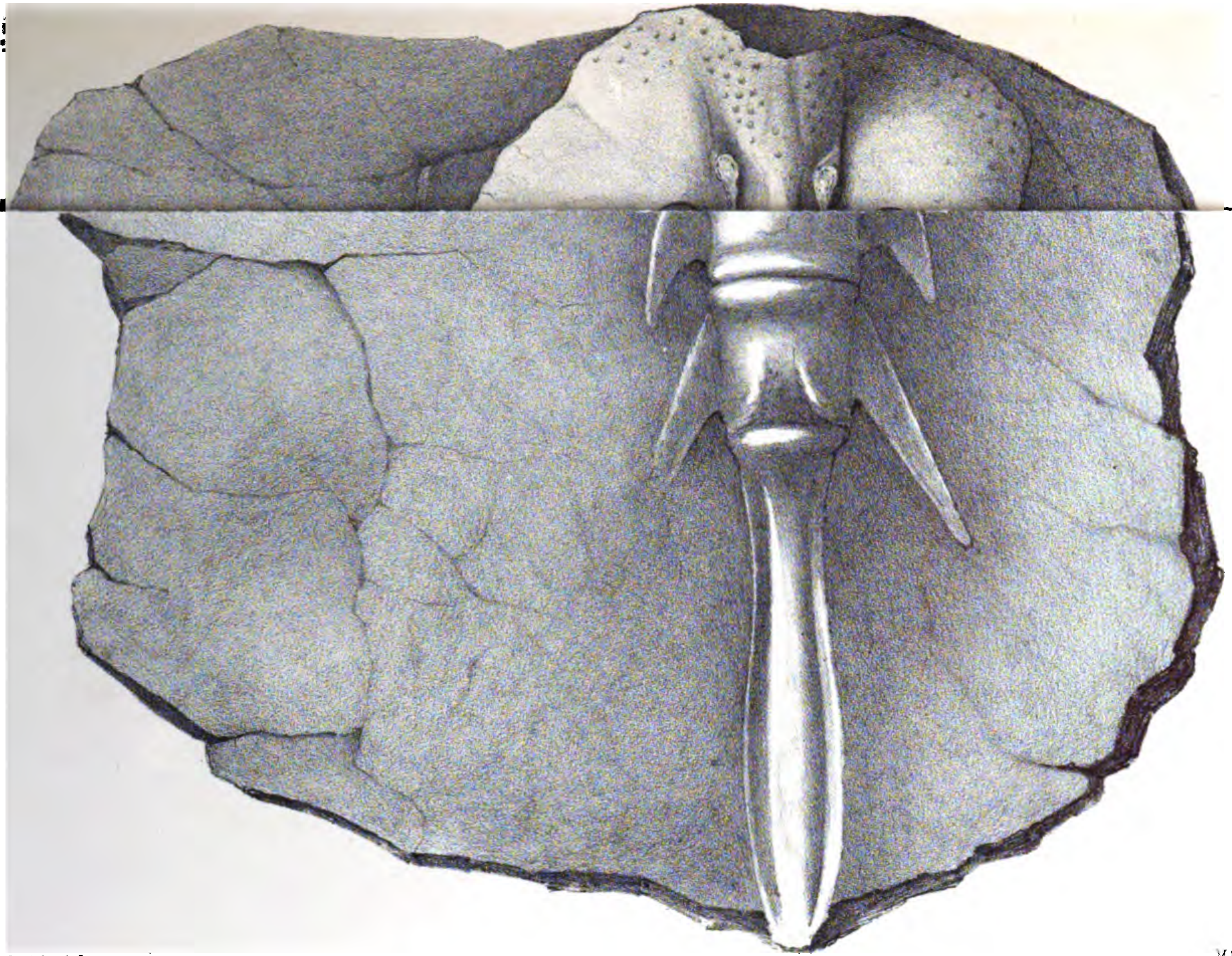
Order—Merostomata.

Sub-Order—Eurypterida.

Stylonurus Scoticus, H. Woodw. A nearly entire specimen, having its dorsal surface exposed on a slab of sandstone, and the last five body-segments detached entire, so as to exhibit both the ventral and dorsal surfaces; reduced to three eighths its natural size, the original specimen measuring three feet four inches in length. (P. 126.)

Lower Devonian, Forfarshire.

From the Collection of James Powrie, Esq., F.G.S., Reswallie, near Forfar.



G.R. De Wilde del et lith.

M&N Hanhart imp.

STYLONURUS SCOTICUS. *H. Woodward.*

L^{r} Devonian, Forfarshire.

PLATE XXIV.

UPPER SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

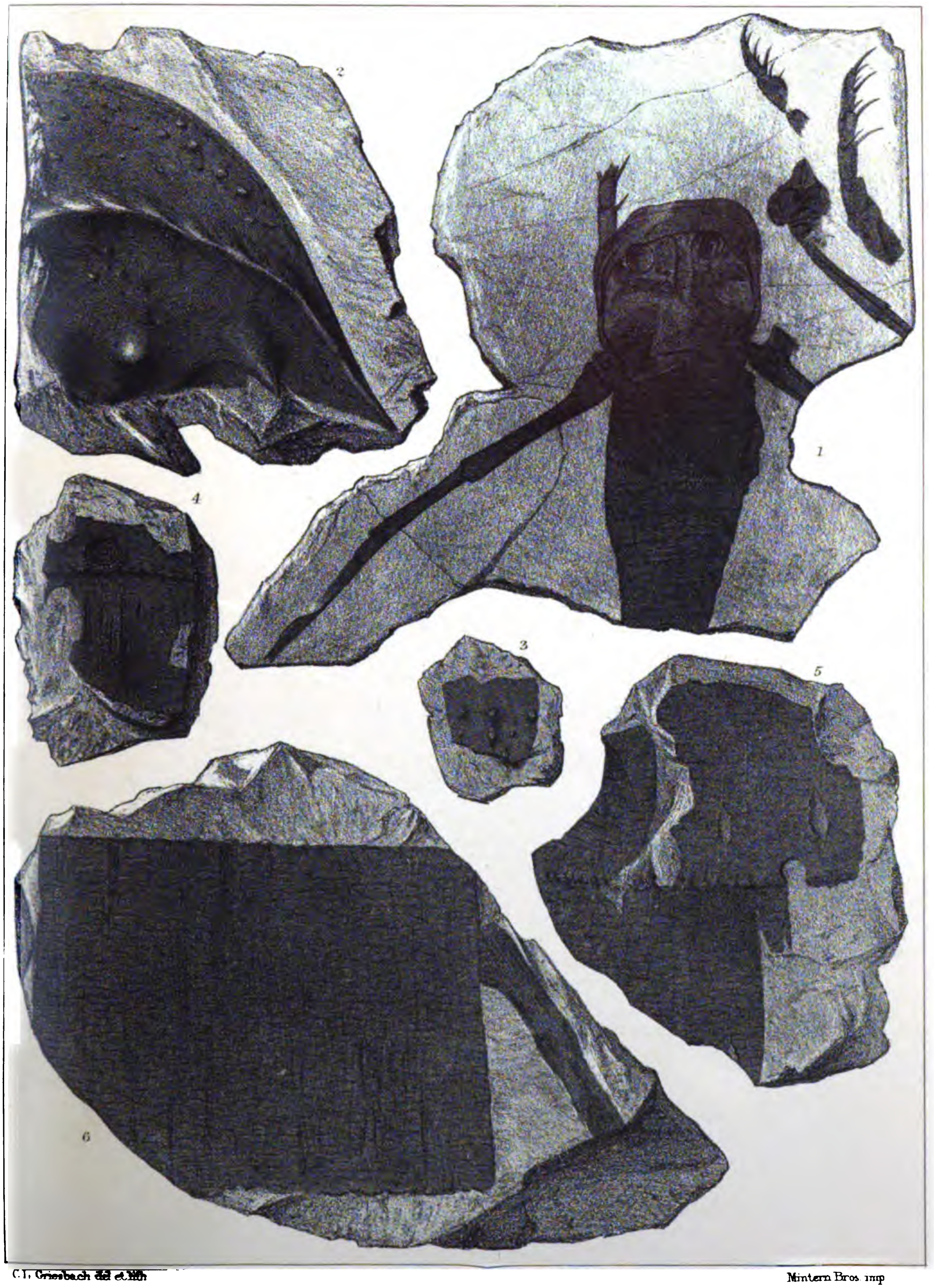
1. *Stylonurus Logani*, H. Woodw. (P. 129.) Drawn of the natural size, from the specimen in the Museum of Practical Geology, Jermyn Street. The Counterpart is in the Collection of James Powrie, Esq. From the Upper Silurian, Lesmahagow, Lanarkshire.

MISCELLANEOUS SPECIMENS.

2—6. Represent the specimens described by Mr. J. W. Salter, under the name of *Eurypterus mammatus*, from the "Ferny Metal," Coal-measures, Pendleton Colliery, Manchester. (See p. 163.)

2 and 3 are referred to M. Jordan's genus *Arthropleura*, under the name of *A. mammata.* (See p. 167.)

4, 5, and 6 are referred to Plant-remains by Mr. Carruthers. (See p. 168.)



C. L. Griesbach del. et lith. Mintern Bros. imp

1. STYLONURUS LOGANI, *H. Woodward.* U. SILURIAN.
2.-6. EURYPTERUS MAMMATUS, *Salter.* COAL MEASURES.

PLATE XXV.

CARBONIFEROUS CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1. *Eurypterus Scouleri*, Hibbert. (P. 133.)

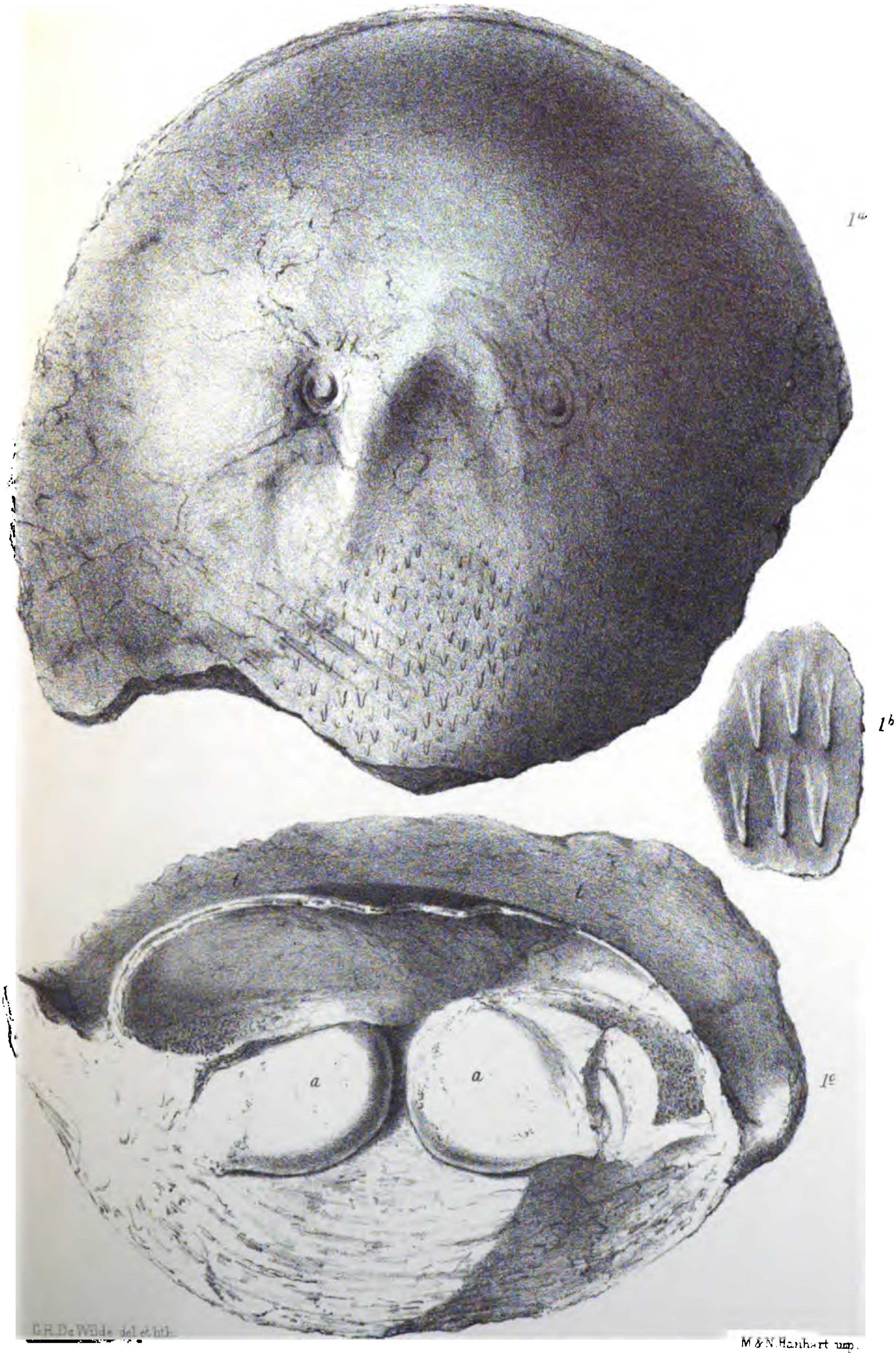
1 *a*. Dorsal aspect of head-shield (natural size), showing position of great subcentral eyes.

1 *b*. The peculiar ornamentation of the posterior border of head (enlarged).

1 *c*. The under side of head exposing *a, a,* the bases of the ectognaths and *t, t,* the thoracic plate ? or operculum, thrust forward out of its natural position behind the mouth, so as to be found overlapping it in its present abnormal position. (See p. 136, and Woodcut, Fig. 41.)

From the Freshwater Limestone, Lower Carboniferous, Burdie House, near Edinburgh.

Coll. of James Powrie, Esq., F.G.S., Reswallie.



G.R. De Wilde del et lith.

M & N Hanhart imp.

EURYPTERUS SCOULERI, *Hibbert*.

PLATE XXVI.

CARBONIFEROUS CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Eight most posterior body-rings of *Eurypterus Scouleri*, Hibbert; natural size. (P. 136.)

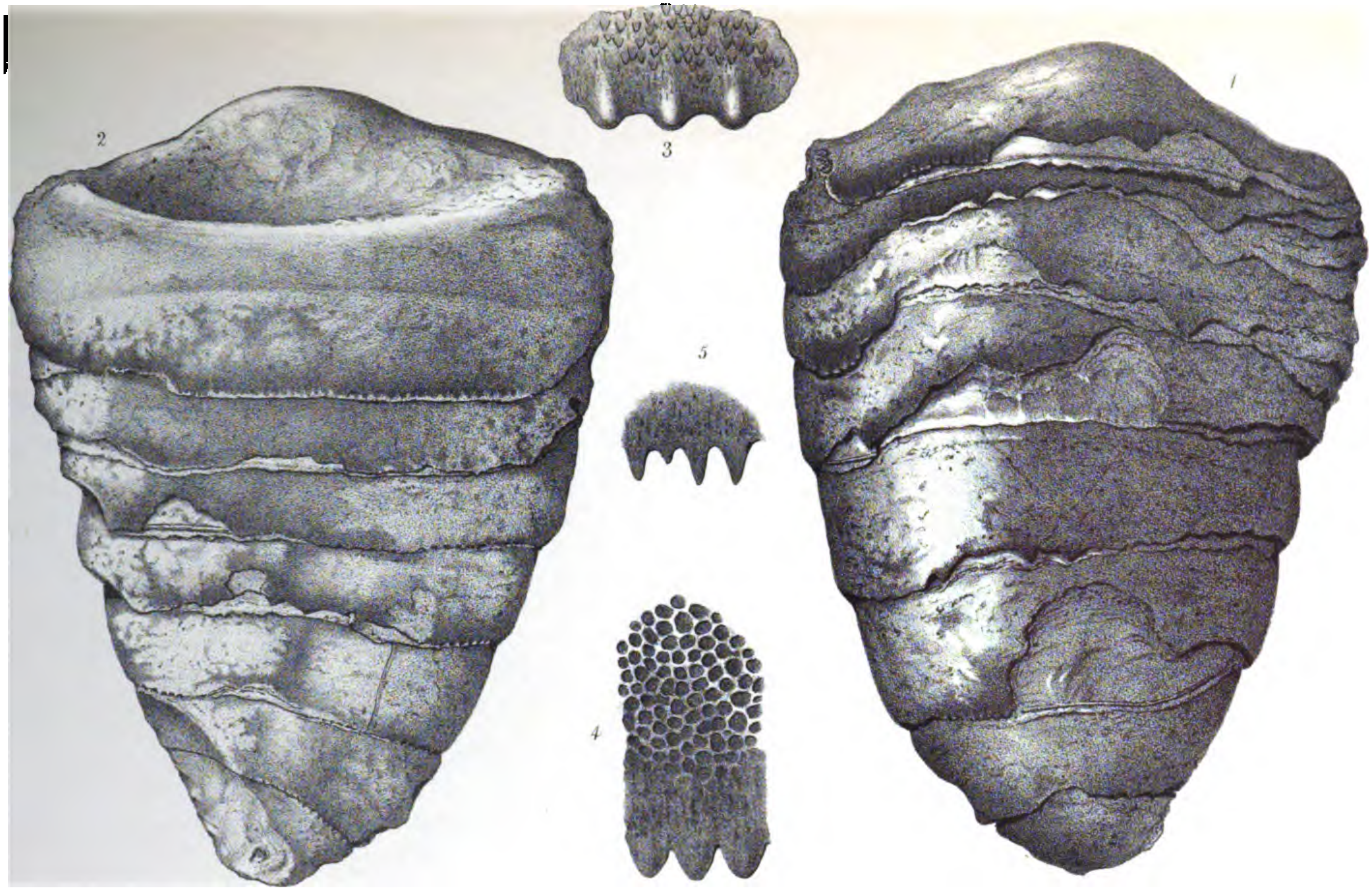
FIG.

1. The dorsal surface.
2. The ventral surface.
3. The characteristic scale-like ornamentation of the dorsal surface, and the spinous border of the segments, magnified.

4 & 5. The characteristic punctate ornamentation of the ventral surface, and the serrated border of the segments, magnified.

From the Freshwater Carboniferous Limestone, Burdie House, Edinburgh.

Coll. of James Powrie, Esq., F.G.S., Reswallie.



C. R. De Wilde del. et lith.

M & N. Hanhart imp

EURYPTERUS SCOULERI, *Hibbert.*

Coal Measures Burdie House, near Edinburgh.

PLATE XXVII.

CARBONIFEROUS CRUSTACEA.

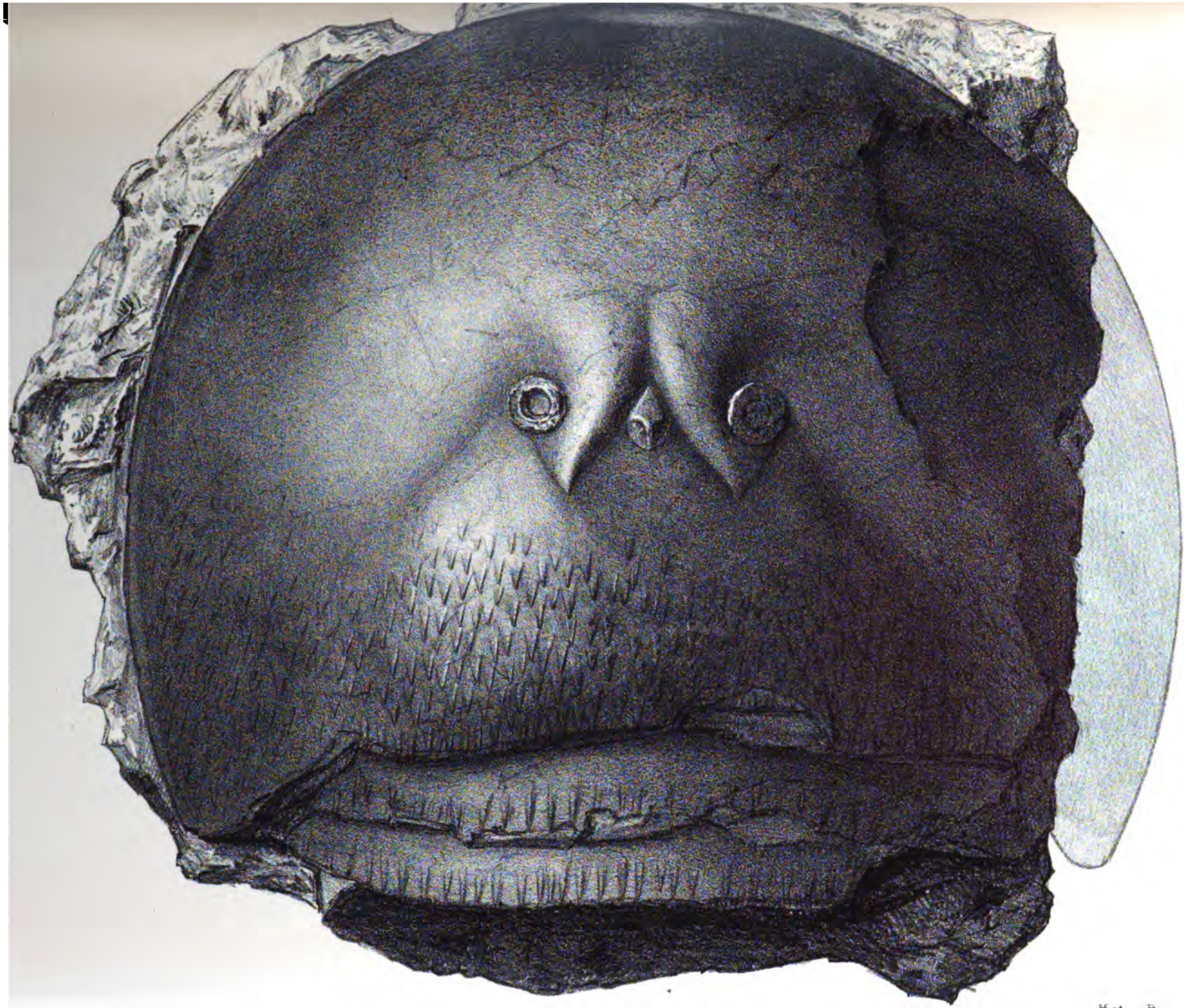
Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

Head-shield of *Eurypterus Scouleri*, Hibbert, with the two most anterior body-segments still united thereto (natural size). (P. 134.)

From the Freshwater Carboniferous Limestone, Burdie House, near Edinburgh.

Coll. Andersonian University Museum, Glasgow.



C.L. Griesbach del et lith

Mintern Bros imp

EURYPTERUS SCOULERI, *Hibbert*.

COAL MEASURES, BURDIE HOUSE, NEAR EDINBURGH.

PLATE XXVIII.

SILURIAN AND DEVONIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIGS.

1—3. *Eurypterus lanceolatus*, Salter.
Uppermost Silurian; Lesmahagow, Lanarkshire. Drawn of the natural size. (P. 140.)

1. The largest specimen obtained. One of the great swimming-feet (ectognaths) and about four of the endognathary palpi are seen lying close to the borders of the head-shield. The impression of the long median appendage of the thoracic plate is also seen underlying the 4th and 5th thoracic somites. (P. 142.)

2 has both the swimming-feet preserved and the thoracic plate (fig. 2 *a*) displaced, so as to show its form completely. In this specimen the median thoracic appendage is short, bifid, and divided into three joints. (P. 143.)

3. The smallest example of *E. lanceolatus* obtained. (P. 143.)
Figs. 1—3 are preserved in the British Museum.

4. *Eurypterus Brewsteri*, H. Woodw. (P. 151.)
Head-shield and ovisac; natural size.
Old Red Sandstone; Kelly Den, near Arbroath.
Coll. James Powrie, Esq., F.G.S., Reswallie, Forfar.

5, 6, 7. *Eurypterus pygmæus*, Salter. (P. 144.)
Fig. 5. Head-shield, thoracic segments, and swimming-foot (nat. size).
Downton Sandstone; Kington.
Coll. R. Banks, Esq., F.G.S., Kington.
Fig. 6. Head-shield, body-joints, and telson (nat. size).
Fig. 7. Body-joints and telson (nat. size).
Basement-beds of the Old Red Sandstone; Ludlow.
Coll. Robert Lightbody, Esq., F.G.S., Ludlow.

8. This series of body-segments are referred by Mr. Salter to *Eurypterus* (now *Stylonurus*) *megalops*; but the telson is broader and shorter than is usual in *Stylonurus*. (P. 146.)

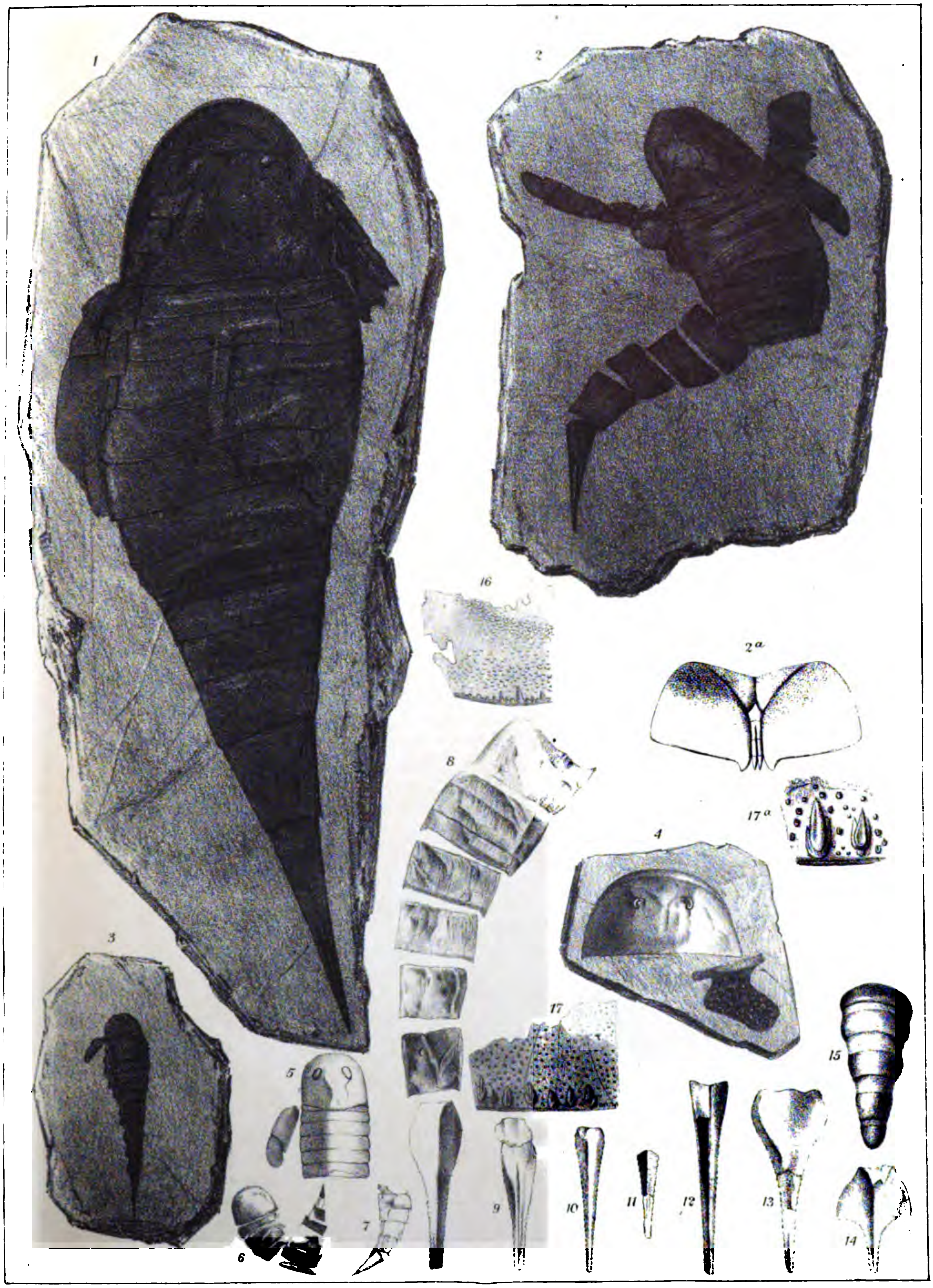
9. Another telson referred to the same species.
Base of the Old Red Sandstone; Ludlow Railway.
Coll. R. Lightbody, Esq., F.G.S.

10—14. A series of detached telsons or tail-spines of *Eurypterus*, described by Mr. Salter.
Figs. 10—12. *E. linearis*, Salter. (P. 147.)
Fig. 10. Upper Ludlow Rock; Ludford, Kington.
Figs. 11 and 12. Downton Sandstone; Kington.
Fig. 13. *E. acuminatus*, Salter. (P. 146.)
Passage-beds, base of the Old Red Sandstone; Ludlow Railway.
Fig. 14. *E. abbreviatus*. (P. 148.)
Downton Sandstone; Kington.

15. Body-segments doubtfully referred to *E. acuminatus*. (P. 146.)

16, 17, and 17A. *Eurypterus Hibernicus*, Baily. (P. 148.)
Upper Old Red Sandstone; Kiltorcan, Co. Kilkenny.
Museum Geol. Surv. Ireland, Dublin.

[Figs. 5—17 copied from the Plate illustrating Mr. Salter's paper. See 'Quart. Journ. Geol. Soc.,' 1859, vol. xv, p. 232, pl. x.]



C. L. Griesbach del et lith

EURYPTERUS.

Mintern Bros imp

PLATE XXIX.

UPPER SILURIAN CRUSTACEA.

Order—Merostomata.

Sub-Order—Eurypterida.

Fig.

1. ***Eurypterus scorpioides,*** H. Woodw. (nat. size). Uppermost Silurian; Lesmahagow, Lanarkshire. (P. 152.)

   Drawn from the original specimen preserved in the British Museum.

2. ***Eurypterus punctatus,*** Salter, sp. One of the swimming-feet or ectognaths (nat. size). Lower Ludlow Rock; Leintwardine. (P. 153.)

   [Copied from Mr. C. R. Bone's pl. xi, fig. 15, illustrating Messrs. Huxley and Salter's Monograph on Eurypterida, 'Memoirs Geol. Surv.,' Mon. I, 1859.]

   Coll. of Mr. H. Pardoe, in the Ludlow Museum.

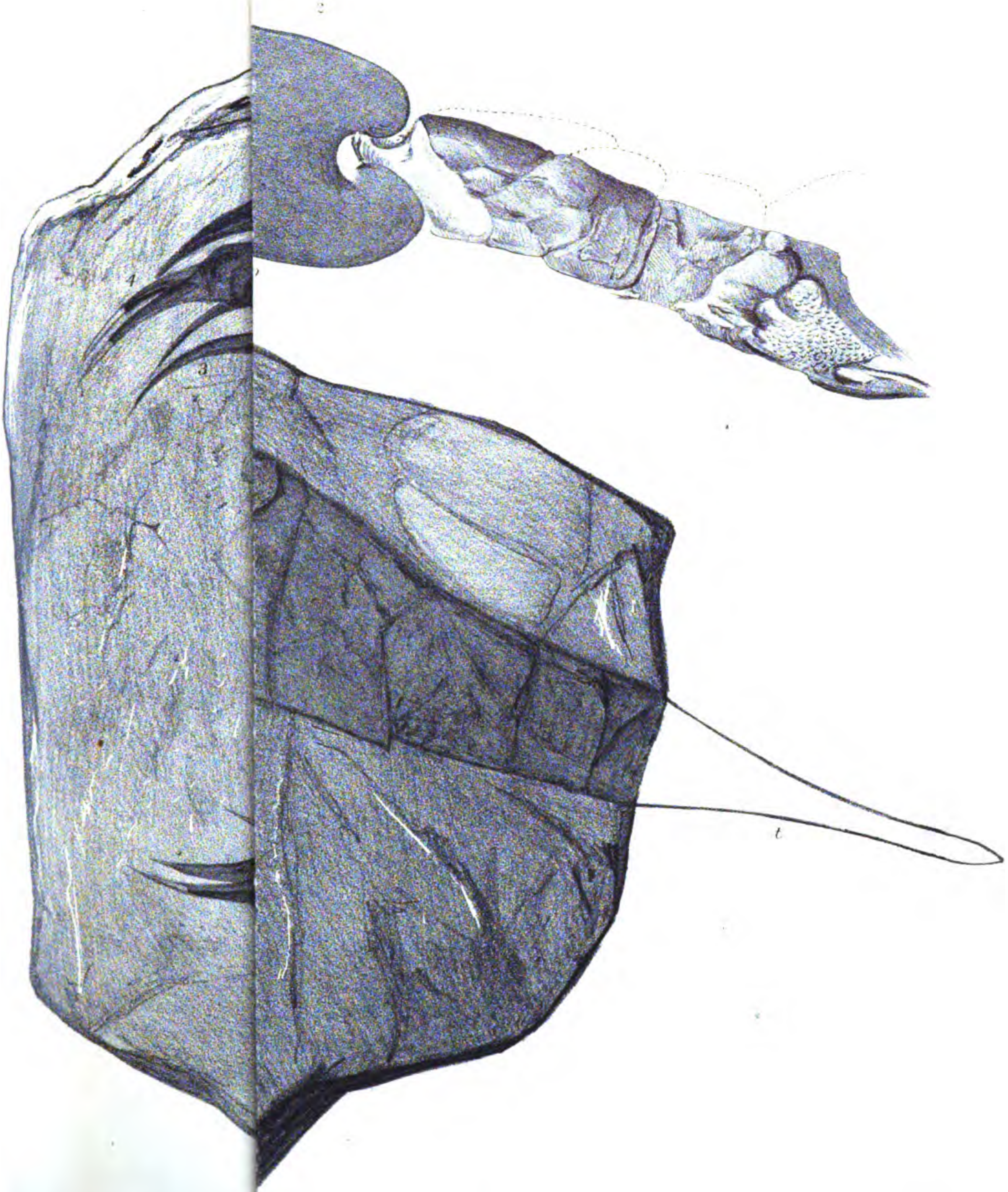


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PLATE XXX.

SILURIAN CRUSTACEA.

Order—MEROSTOMATA.

Sub-Order—EURYPTERIDA.

FIG.

1—7. *Hemiaspis*, H. Woodward (nat. size).

1 & 2. *H. limuloides*, H. Woodw. (P. 174.)

Lower Ludlow ; Leintwardine.

1. Preserved in the Museum of Practical Geology, Jermyn Street.
2. Preserved in the British Museum.

3. Fragment of a head-shield of *Hemiaspis*. Brit. Mus.

4. *H. Salweyi*, Salter. (P. 179.)

Lower Ludlow ; Ledbury.
Coll. British Museum.

5 & 7. *H. speratus*, H. Woodw. (P. 178.)

Lower Ludlow ; Leintwardine.
Coll. British Museum.

6. *Hemiaspis horridus*, H. Woodward. (P. 179.)

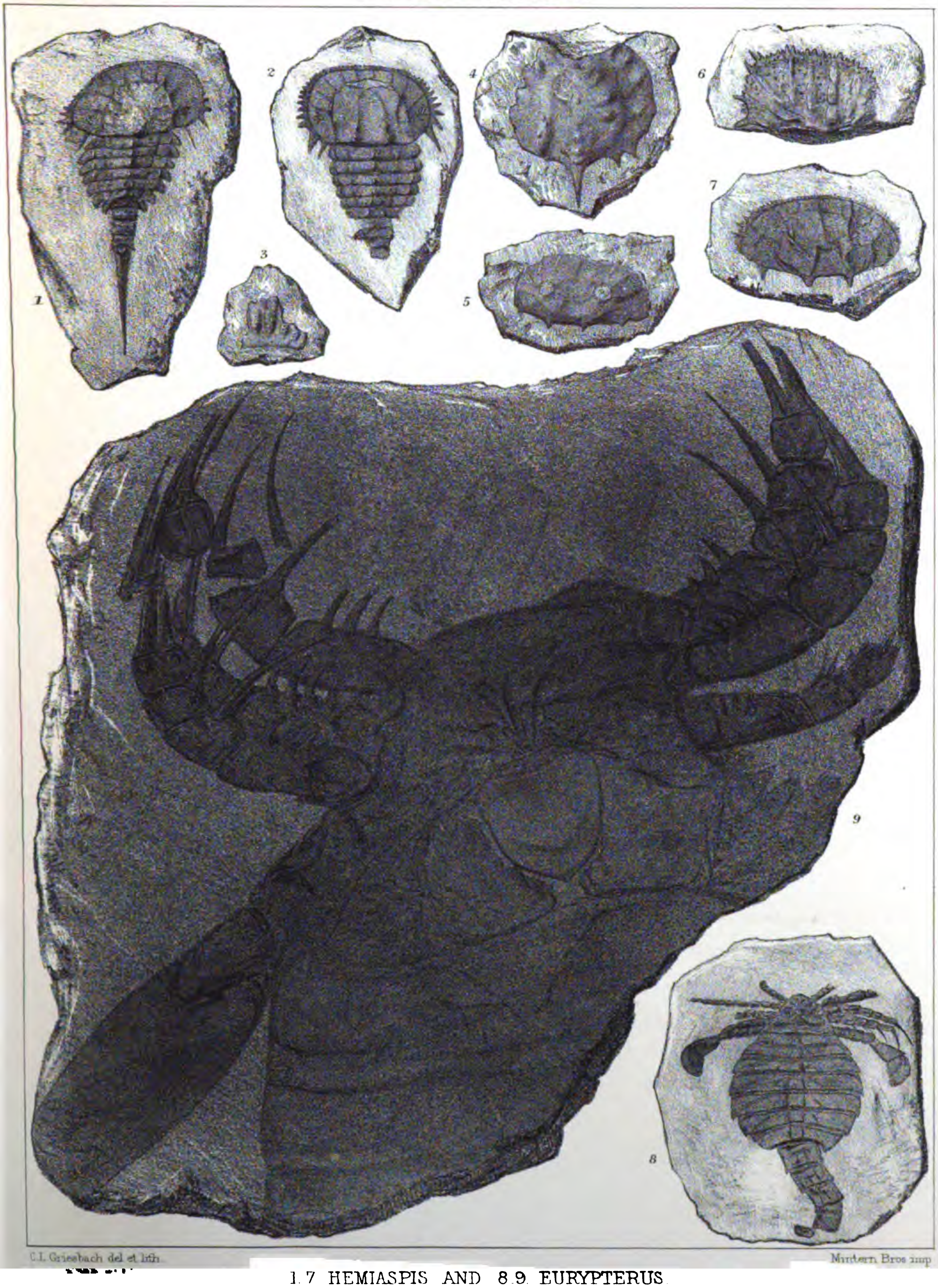
Wenlock Shale ; Dudley.
Coll. British Museum.

8. *Eurypterus obesus*, H. Woodw. (nat. size).

Uppermost Silurian ; Lesmahagow, Lanarkshire. (P. 160.)
Coll. British Museum.

9. *Eurypterus scorpioides*, H. Woodw. Counterpart of fig. 1, Pl. XXIX. (P. 152.)

Uppermost Silurian ; Lesmahagow, Lanarkshire.
Coll. British Museum.



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1. 7 HEMIASPIS AND 8. 9. EURYPTERUS.

PLATE XXXI.

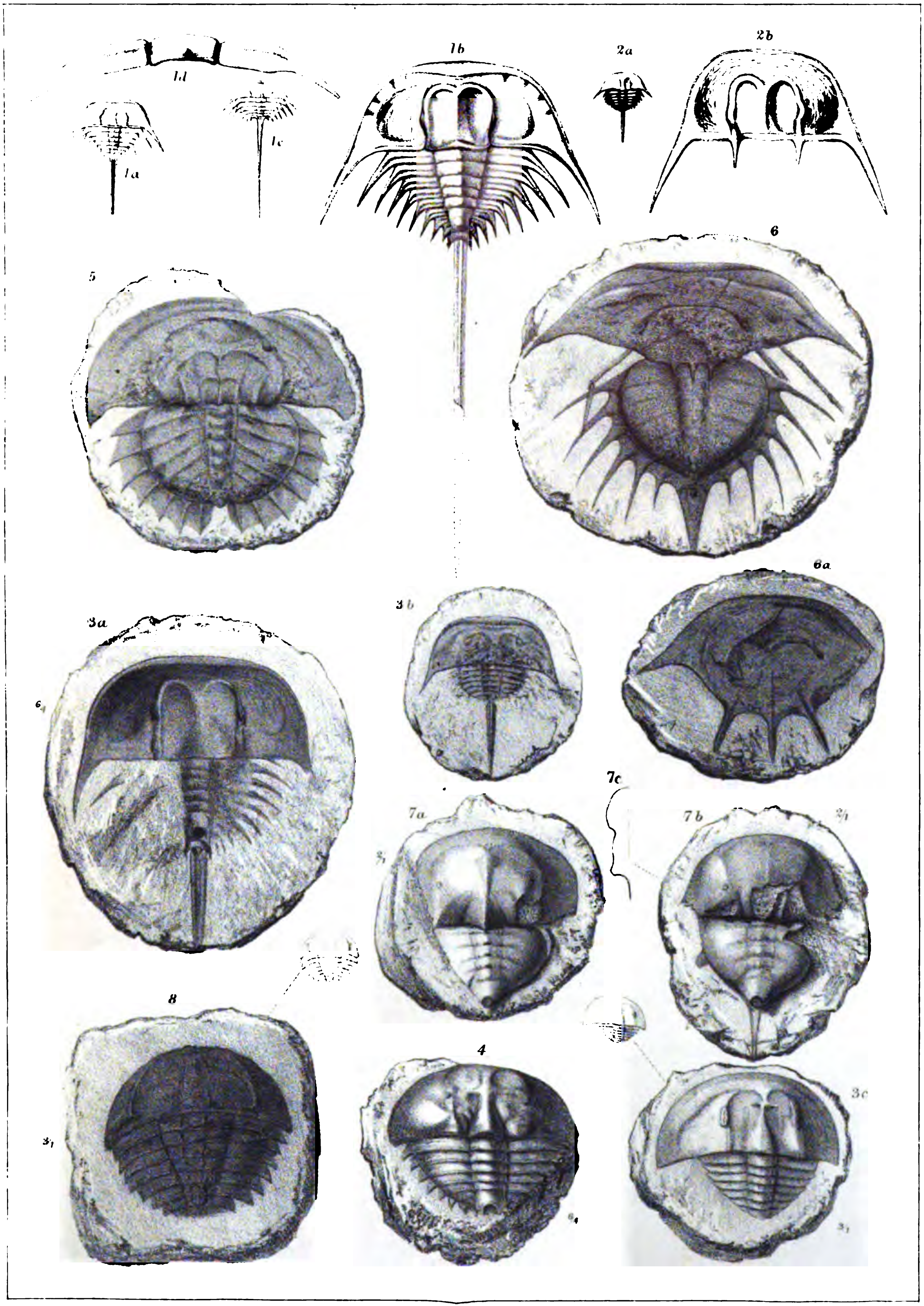
SILURIAN AND CARBONIFEROUS CRUSTACEA.

Order—Merostomata.

Sub-Order—Xiphosura.

Fig.	
1.	*Bellinurus reginæ*, Baily, 1863. (P. 240.) Coal-measures, Queen's County, Ireland. Museum of the Geol. Survey of Ireland, Dublin.
1 *a*, 1 *c*.	Specimens drawn of the natural size.
1 *b*.	The same greatly enlarged.
1 *d*.	One of the thoracic somites enlarged.
2.	*Bellinurus arcuatus*, Baily, 1863. (P. 241.) Coal-measures, Queen's County, Ireland. Museum of the Geol. Survey of Ireland, Dublin.
2 *a*.	Specimen drawn of the natural size.
2 *b*.	A head-shield greatly enlarged.
3.	*Bellinurus bellulus*, König, 1820. (P. 239.) Coal-measures, Coalbrook Dale, Shropshire, &c.
3 *a*.	The original specimen in the cabinet of Prof. Prestwich, F.R.S. (enlarged).
3 *b*.	Specimen originally figured by Buckland, and now in the British Museum.
3 *c*, & 4.	*Bellinurus Kœnigianus*, H. Woodw., 1872. (P. 243.) Coal-measures, Dudley Coal-field. Both figures are enlarged. Original specimens in the British Museum.
5.	*Prestwichia rotundata*, H. Woodw., 1867. (P. 246.) Coal-measures, Coalbrook Dale. (Natural size.) The original specimen in the cabinet of Prof. Prestwich, F.R.S.
6.	*Prestwichia anthrax*, H. Woodw., 1867. (P. 244.) Coal-measures, Coalbrook Dale. (Natural size.)
6, & 6 *a*.	The original specimens in the cabinet of Prof. Prestwich, F.R.S., &c.
7 *a*, *b*, *c*.	*Prestwichia Birtwelli*, H. Woodw., 1872. (P. 247.) Coal-measures, near Padiham, Lancashire. (Enlarged twice the natural size.) 7 *c*, profile. The original specimens in the collection of Mr. Thomas Birtwell, Gawthorpe Gardens, Padiham, Lancashire.
8.	*Neolimulus falcatus*, H. Woodw., 1868, enlarged. (P. 233.) Upper Silurian, Lesmahagow, Lanarkshire. The natural size given in outline. The original specimen preserved in the British Museum.

SUB-ORDER XIPHOSURA.



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LIMULI FROM THE CARBONIFEROUS & SILURIAN FORMATIONS

PLATE XXXII.

SILURIAN AND CARBONIFEROUS CRUSTACEA.

Figs.

1—39. Developmental stages of Trilobita (after Barrande).

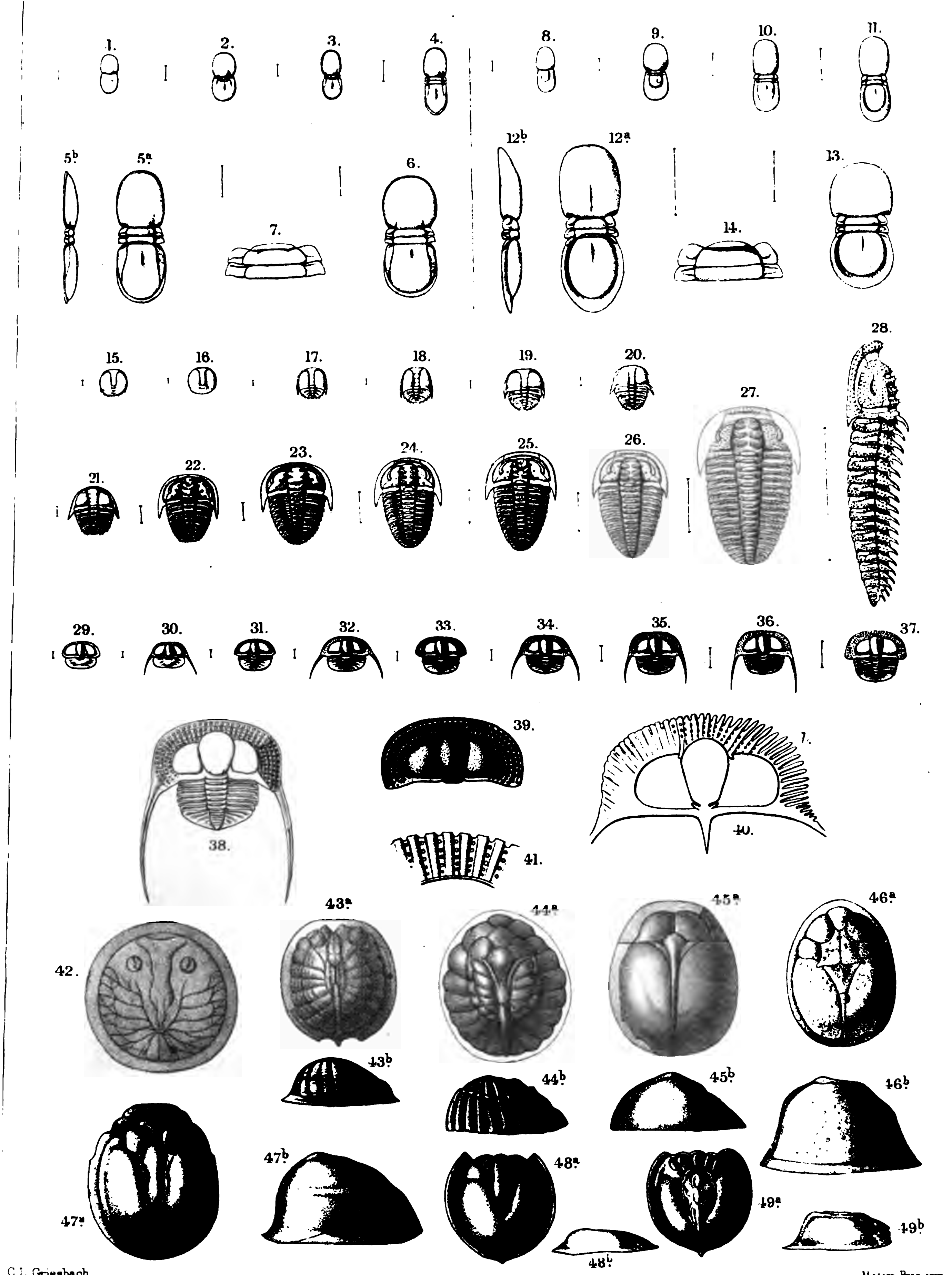
1—7. *Agnostus bibullatus*, Barr., 'Syst. Silur. de Bohême,' pl. xlix, p. 906, étage C, Skrey, Bohemia.
Fig. 1. Cephalon and pygidium only observable.
2. „ „ and two soldered thoracic somites.
3. „ „ one soldered and one free.
4. „ „ „ and two free.
5 *a*, *b*. „ „ „ thoracic somites (form long).
6. „ „ „ „ (form broad).
7. The free thoracic segments seen enlarged.

8—14. *Agnostus nudus*, Beyr., 'Barr. Syst. Silur. de Bohême,' pl. xlix, p. 903, étage C, Skrey, Bohemia.
Fig. 8. Cephalon and pygidium only observable.
9. „ „ and two soldered thoracic somites.
10. „ „ and one soldered and one free thoracic somites.
11. „ „ and two free thoracic somites.
12 *a*, *b*. „ „ „ „ (form long).
13. „ „ „ „ (form broad).
14. The two free thoracic somites seen enlarged.

15—28. *Sao hirsuta*, Barr., 'Syst. Silur. de Bohême,' pl. vii, étage C, Skrey, Bohemia.
Figs. 15 and 16. Two individuals in which there is no line of separation between the head and the pygidium; in Fig. 15 a slight indication on the axis marks the commencement of the division of the body into somites; the glabella is also marked by a simple fold on the cephalic portion.
Fig. 17. Shows the second stage with three soldered somites; the thorax is indicated (form broad).
18. The third stage. The genal spines and the points of the pleuræ are well seen; four to five soldered somites are indicated.
19. Fifth stage. Thorax longer than head, with three free and three soldered somites (form broad).
20. The same degree of development as Fig. 19 (form long).
21. Broad form, with four free segments and three or four soldered segments.
22. Tenth stage. Form broad; eight free and three soldered segments; the compound eyes are seen at this stage.
23. Twelfth stage. Form broad; ten free and three to four soldered somites; the eyes and ornament on the head are seen.
24. Fourteenth stage. Form long; twelve free and two to four soldered somites; four lobes marked on glabella.
25. Sixteenth stage. Form long; fourteen free and three soldered somites.
26. Eighteenth stage. Form long; sixteen free and three soldered somites; the number of somites is completed at this stage.
27. Twentieth stage. Form long; all the segments of the thorax and pygidium are very distinct; seventeen free somites and two soldered. The ornamentation at this stage assumes all the characters of the adult.
28. View in profile, restored from numerous fragments, showing all the ornamentation of the test. (P. 223.)

29—39. *Trinucleus ornatus*, Sternb., 'Barr. Syst. Silur. de Bohême,' pl. xxx, p. 624, étage D, Trubin.
Fig. 29. Young, with no thoracic segments, and without genal spines.
30. „ „ „ and with „
31. „ one „ without „
32. „ „ „ and with „
33. „ two „ without „
34. „ „ „ and with „
35. „ three „ „ „
36. „ four „ „ „
37. „ five „ without „
38. Adult, one part of the test on the right genal border preserved.
39. „ head-shield without genal spines.

40. *Trinucleus ornatus*, Sternb., 1833. Hypothetical development of the fringe of glabella, after Salter.
41. Fringe of *Trinucleus fimbriatus*, Murch., 1839.
Figs. 40 and 41 illustrate Mr. Salter's paper, 'Quart. Journ. Geol. Soc.,' 1847 (vol. iii, p. 252, woodcuts). (P. 218.)
42. *Cyclus Rankini*, H. Woodw., 1868. (P. 254.) Coal-shales, Carluke, Scotland (diameter 4 lines).
43. — *radialis*, Phillips, sp., 1829. (P. 253.) Carboniferous Limestone, Settle and Bolland, Yorkshire.
a, dorsal aspect; *b*, side-view.
44. — *Harknessi*, H. Woodw., 1870. (P. 252.) Carboniferous Limestone, Little Island, Cork, Ireland.
a, dorsal aspect; *b*, side-view.
45 — *bilobatus*, H. Woodw., 1870. (P. 249.) Carboniferous Limestone, Settle, Yorkshire.
a, dorsal aspect; *b*, side-view.
46. — *Jonesianus*, H. Woodw., 1870 (P. 254) (magnified four times). Carboniferous Limestone, Little Island, Cork, Ireland.
a, dorsal aspect; *b*, side-view.
47. — *Wrightii*, H. Woodw., 1870. (P. 251.) Carboniferous Limestone, Little Island, Cork, Ireland.
a, dorsal aspect; *b*, side-view.
48. — (*Halicyne*) *laxus*, H. von Meyer, sp. (P. 255.) Muschelkalk, Rottweil, Germany.
a, dorsal aspect; *b*, side-view.
49. — (*Halicyne*) *agnotus*, H. von Meyer, sp. (P. 255.) Muschelkalk, Rottweil, Germany.
a, dorsal aspect; *b*, side-view.



C L Griesbach.

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Figs. 1–41. DEVELOPMENT OF AGNOSTUS, SAO, AND TRINUCLEUS. (*after Barrande.*)
Figs. 42–47. CYCLUS, CARBONIFEROUS. Fig 48 & 49. HALICYNE, TRIASSIC.

PLATE XXXIII.

Order—Merostomata.

Sub-Order—Xiphosura.

Larval stages of *Limulus polyphemus*, Latr.

Figs.

1. The embryo enclosed within its two membranous egg-envelopes, the inelastic "chorion," and the inner elastic "protoderm" (*y*). The primitive disc is seen marked off from the main yolk-mass (*p m*), and bearing the mouth (*m*) and the six pairs of finger-shaped, rudimentary cephalic limbs (*a—f*). Copied from Dr. Packard's 'Memoir,' op. cit., pl. iii, fig. 13. (P. 215.)

2. The beginning of the "sub-zoëan stage," in which two pairs of thoracic appendages (*g*, *h*) are added to the six pairs seen in Fig. 1, and the appearance of segmentation on the back of the embryo (*p m*). Copied from Packard, pl. iv, fig. 16. (P. 215.)

3. Ventral aspect, and 4. Side-view of embryo. The thoracico-abdominal division (T, A) is now clearly differentiated from the head (C), with the segments well marked. The five (or six?) lobes of the liver indicating five (or six?) cephalic somites (see Fig. 4 *c*), A third pair of thoracic appendages are added (Fig. 4 *i*). Copied from Packard, pl. iv, figs. 19, 19 *a*. (P. 216.)

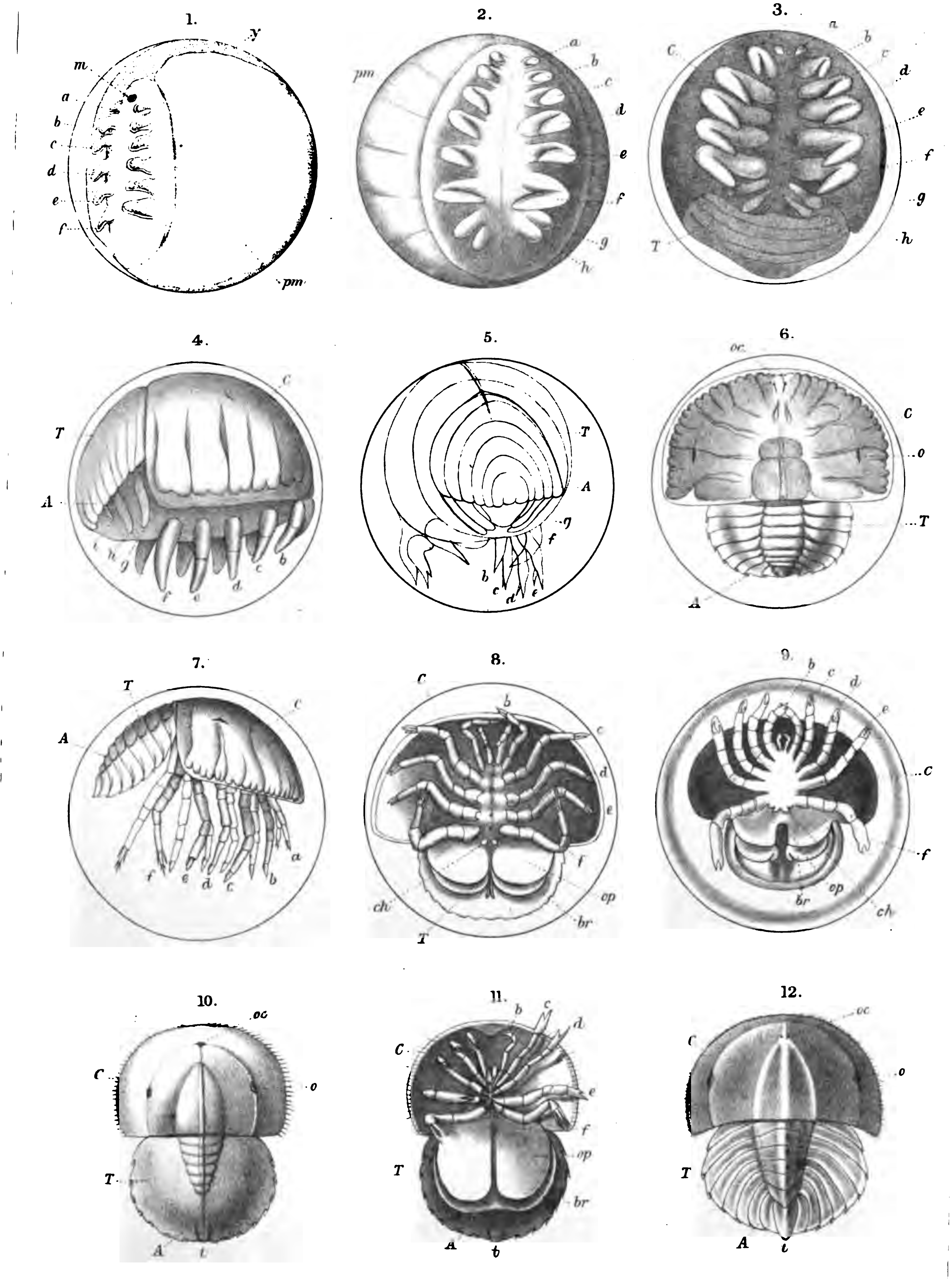
5. Posterior view of an older individual, showing the thoracico-abdominal segments, the cephalic limbs, and the three pairs of thoracic branchial feet and the dorsal heart. Copied from Packard, pl. iv, fig. 20. (P. 217.)

6. The dorsal aspect; Fig. 7, the side-view or profile; and Fig. 8, the ventral aspect of the same embryo just before hatching; *oc*, the ocelli; *o*, the compound eyes; *ch*, the "chilaria" or "metastoma;" *op*, the opercular plate; *br*, the branchial plate. The other letters correspond with the same parts in previous figures of the earlier stages of the embryo. Copied from Packard, pl. v, figs. 24, 24 *a*, 24 *b*. (P. 218.)

9. Ventral aspect of another embryo somewhat less advanced than Fig. 8 (copied from Dr. Anton Dohrn). The "chorion" is split, and the embryo is seen to revolve within the expanded "protoderm." The letters correspond with those marked on the embryos in earlier stages. (P. 219.)

10. Dorsal aspect; and Fig. 11, ventral aspect of freshly hatched young of ***Limulus polyphemus***. Copied from Packard, pl. v, figs. 25 and 25 *a*. (P. 220.)

12. Nearly the same stage as the foregoing (copied from Dr. Anton Dohrn). This is Dohrn's "Trilobitenstadium." (P. 220.)



C. L. Griesbach.

Mintern Bros.

LARVAL STAGES OF LIMULUS POLYPHEMUS, LATR.
(after Dohrn & Packard.)

PLATE XXXIV.

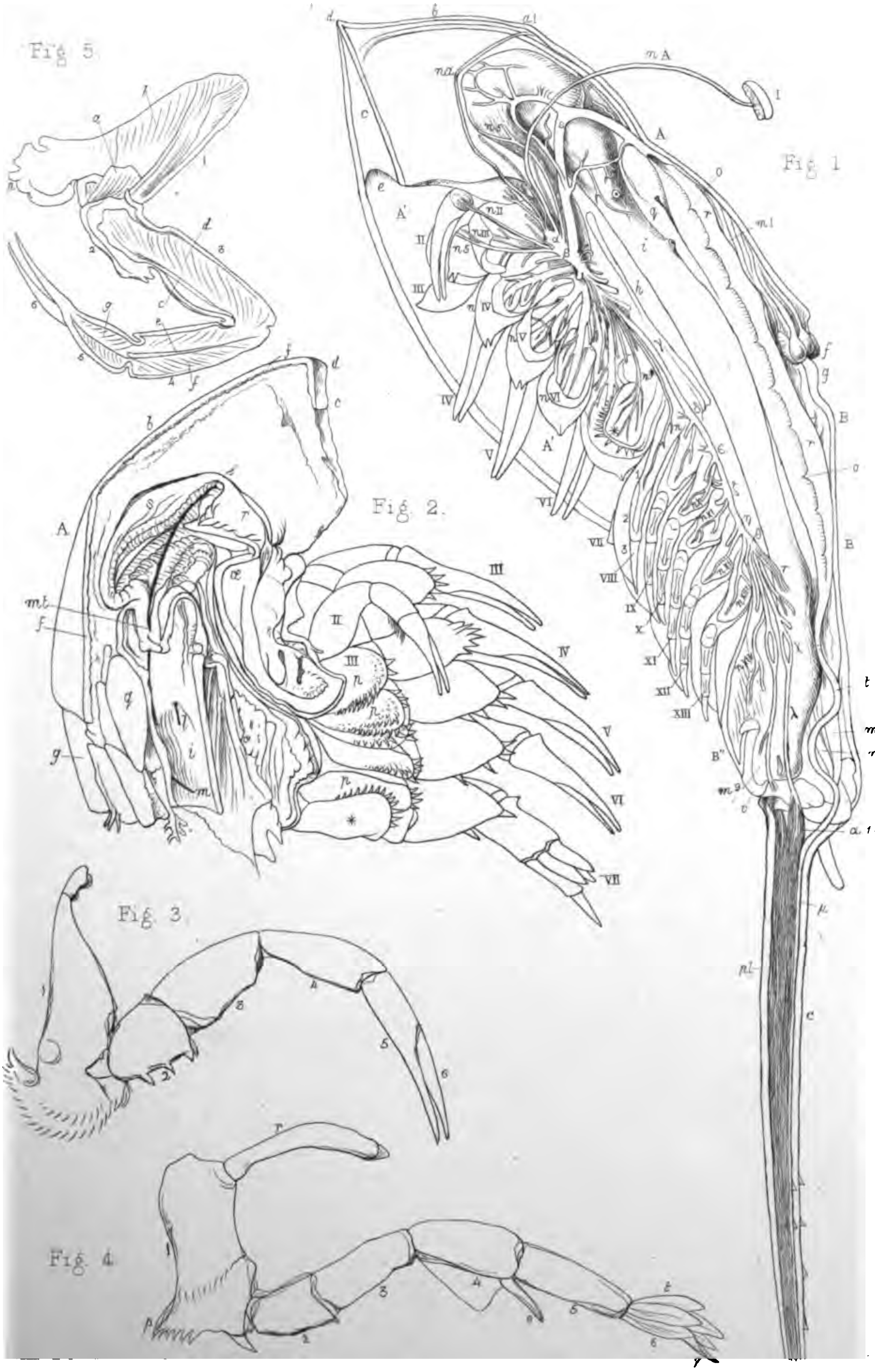
Order—MEROSTOMATA.

Sub-Order—XIPHOSURA.

Anatomy of *Limulus polyphemus*, Latr. (after Owen). (Pp. 186—209.)

FIGS.

1. Side-view of heart, alimentary canal, and nervous system (seen in a longitudinal section).
   - A. Cephalon ("Cephaletron," Owen).
   - B. Thoracico-abdominal somites coalesced ("Thoracetron," Owen).
   - C. Telson ("base of Pleon," Owen).
   - A′. Under or vaulted surface of cephalon.
   - B″. Rudimentary abdomen ("anal segment of Thoracetron," Owen).
     - I. The compound eye. *a* 1. Ocelli. II. Antennule. III. Antenna. IV. Mandible. V. First maxilla. VI. Second maxilla. [In Fig. 1 the forcipated foot of the maxilliped VII has not been indicated by the artist, but see VII, Fig. 2.] VII. Maxilliped. VIII. Operculum. IX—XIII. The five branchial feet.
     - *b*. Dorsal wall of cephalon. *c*. Ventral wall of cephalon. *d*. Digging border of head-shield. *e*. Holding border of cephalon. *f*. Hinder border of cephalon. *g*. Entering process of thorax. *h*. Entosternon. *i*. Intestine. *m* 1. Levatores thoracetri. *m* 7. Levatores telsoni. *m* 8. Obliqui telsoni. *m* 9. Depressores telsoni. *n a*. Ocellar nerve. *n* A. Ocular nerve. *n* II. Antennular nerve. *n* III. Antennal nerve. *n* IV. Mandibular nerve. *n* V. Premaxillary nerve. *n* VI. Maxillary nerve. *n* VII. Maxillipedal nerve.
2. Section through anterior part of cephalon, showing gastric cavity and buccal orifice with maxillipeds, numbered as in Fig. 1. (Pp. 190, 201, 202.)
3. A detached maxilla showing the articulations and the palpus. (P. 186.)
4. A detached maxilliped (for nomenclature of joints see p. 6, Part I, of this Monograph). (P. 190.)
5. Section of one of the maxillæ to show the muscles. (P. 187.)



ANATOMY OF LIMULUS POLYPHEMUS, LATR. (after Owen.)

PLATE XXXV.

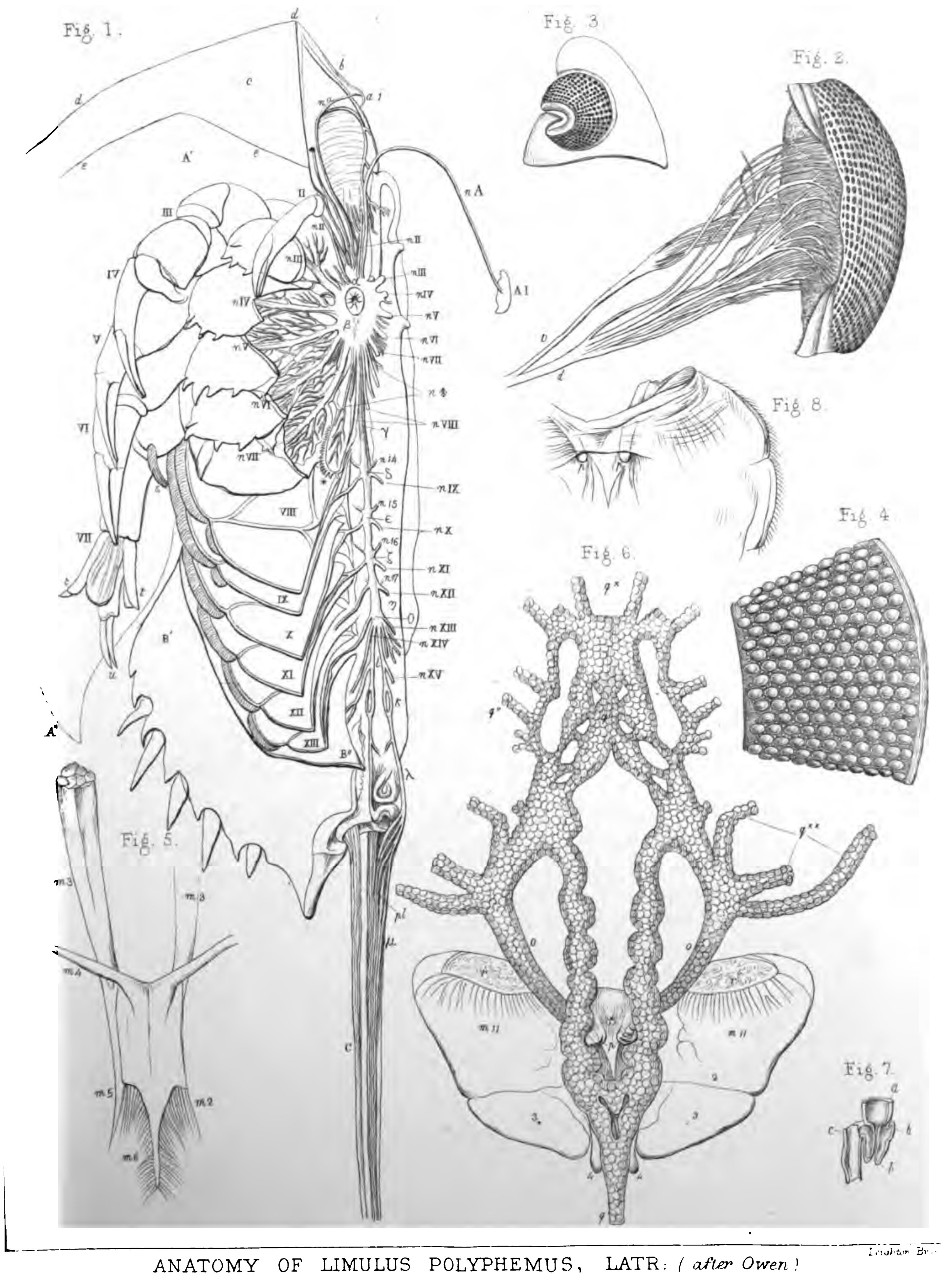
Order—Merostomata.

Sub-Order—Xiphosura.

Anatomy of *Limulus polyphemus*, Latr. (after Owen).

Fig.

1. The nervous system, seen from the lower or ventral aspect. (Pp. 192—198.)
    A′. Inferior surface of cephalon. A″. Posterior point of lateral or *genal* portion of the cephalon. B′. Infero-lateral surface. B″. Infero-median surface of thoracetron (thoracico-abdominal shield). *n* xv. Nerve of anal segment. (The other letters are the same as in Pl. XXXIV.)
2. Compound eye and terminations of ocular nerve, from the dorsal aspect; magnified 6 diameters. (P. 192.)
    d. Dorsal branch and divisions of ocular nerve. *v*. Ventral branch and divisions of ocular nerve.
3. Compound eye of a Trilobite (*Phacops*), magnified 3 diameters.
4. Portion of the same compound eye, magnified 10 diameters.
5. Entosternon and attached parts of muscles; after vander Hoeven. (P. 187.)
6. Chief parts of ovarium, oviducts, and opercular plate (upper or inner surface). (P. 208.)
    m' 11. Muscles of operculum. *o*, *o*. Oviducts. *p*. Oviducal outlets. *q*. Postero-median lobe of ovary. q^*. Antero-median lobe of ovary. q''. Antero-lateral loops and branches. q^{**}. Postero-lateral cephalic branches. *r*, *r*. Articular surfaces of opercular plate. 2. Second joint of opercular plate. 3. Third joint. 4. Median appendages of opercular plate.
7. Section of terminal part of oviduct (after vander Hoeven).
    a. Oviduct. *b*. Anterior labium. *c*. Part of opercular plate.
8. Portion of opercular plate with terminations of the sperm-ducts, *p*, *p*; after vande Hoeven. (P. 209.)



ANATOMY OF LIMULUS POLYPHEMUS, LATR: (*after Owen*)

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PLATE XXXVI.

Order—Mérostomata.

Sub-Order—Xiphosura.

Anatomy of *Limulus polyphemus*, Latr. (after Owen).

Fig.

1. Nervous system seen from the upper or dorsal aspect. (Pp. 192—198.)
    a. Supra-œsophageal mass. B. Œsophageal ring. *n a.* Ocellar nerve. *n* A. Ocular nerve. *n* 3. Gastric nerve. *n* 4. First epimeral nerve. *n* 5. Second epimeral nerve. *n* 6. Its recurrent branch. *n* 7 to *n* 19. Third to fifteenth epimeral nerves. *pl.* Pleonal plexus.
2. Left branchigerous limb with attached branchiæ. (P. 207.)
3. Branchial lamellæ. *a.* Efferent plexus. All the figures, save where otherwise stated, are of the natural size.

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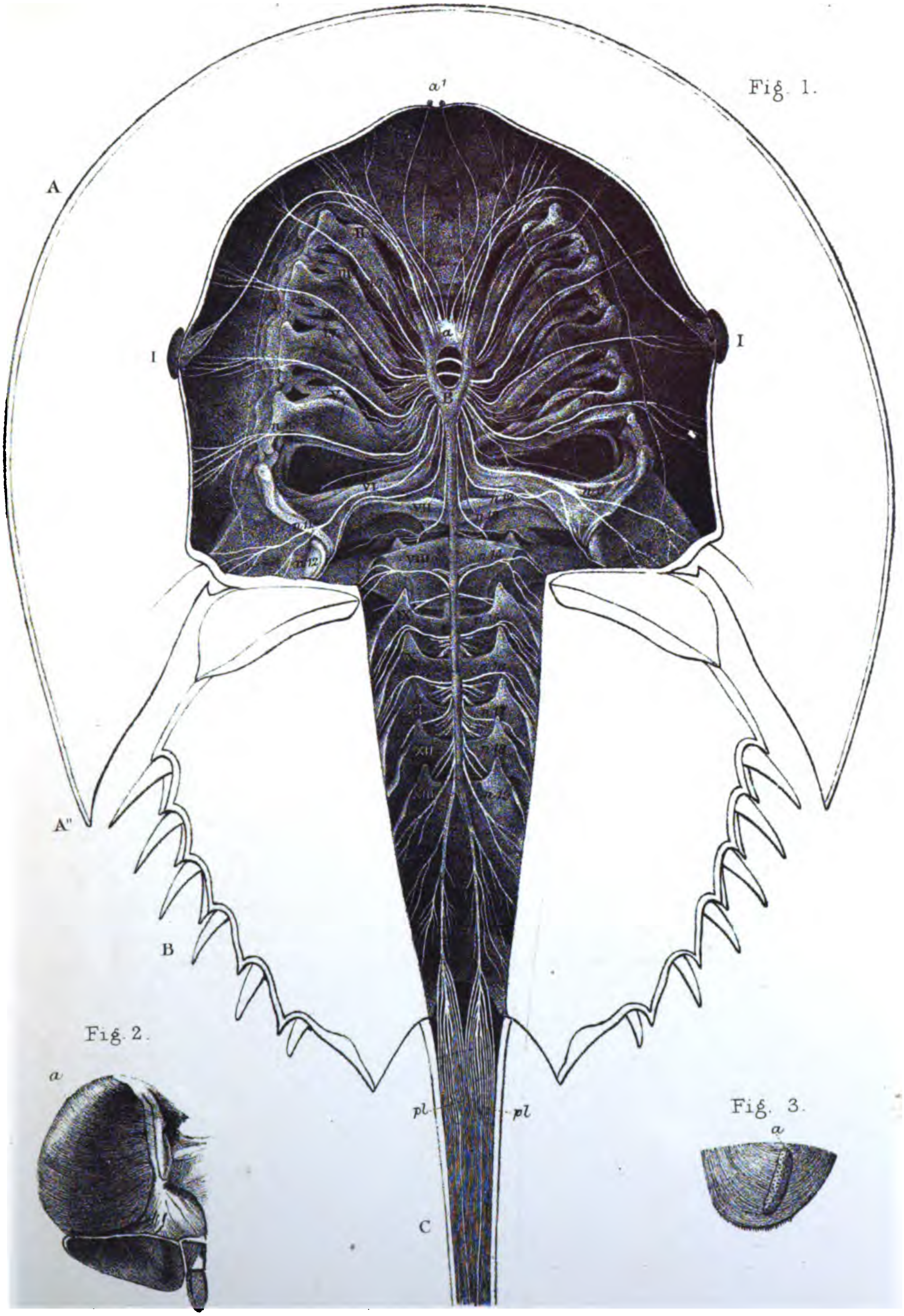

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ANATOMY OF LIMULUS POLYPHEMUS, LATR. (*after Owen.*)